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OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXIII.

NOTES ON THE ANATOMY OF GRASS ROOTS.

By A. P. Goossens,

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(With seven Text-figures.)

(Read March 21, 1934. Revised MS. received June 6, 1934.)

It is remarkable to note that although the subject of ecology was introduced relatively recently in the study of botany extensive work has already been done on the anatomy of grasses. Dr. M. Henrici (1929) must be credited for being one of the first in South Africa to investigate the anatomy of grass roots to see what light it could throw on the wilting and osmotic phenomena, which she studied at Armoedsvlakte, Vryburg. She noticed that the roots of the various grasses she examined differed considerably, and ascribed it to the influence of edaphic and climatic factors.

It is generally accepted that a wet habitat comes nearest to the original under which the Angiosperms have developed. Bews (1929) also maintains that the primitive grasses are more or less still confined to hygrophilous conditions. Away from this type of habitat they have adapted themselves to mesophytic and xerophytic conditions. As Jeffrey (1917) has pointed out, the root is a very conservative organ, but as it is closely connected with the water requirements of the plant it may be expected that in the different habitats it has become specialised for water absorption; the high osmotic pressure of the cell contents of xerophytic and halophytic plants need only be mentioned.

Where we have to face the fact that our pastoral veld has deteriorated and that we are compelled to study the factors which have a direct bearing on its welfare or set back, it is not only necessary to make a study of the life-history but also of the anatomical features both of the aerial and the subterranean organs of our grasses. This would also throw much light on the required treatment of the plants when transplanted and cultivated. A study of the anatomy of the roots of grassses may also throw much light on such phenomena as root development, root competition, and plant succession.

In order to investigate the influence of the climate and the different edaphic conditions on the development and anatomy of the roots, several of the grasses were also grown in water- and soil-cultures. In these cases grass plants obtained from tufts in the veld were used. The roots of these plants were cut off 2 or 3 inches below the root stock before they were planted. The roots of the culture plants as well as that of the veld plants were examined weekly right through the year, and the points of interest noted. In digging up the roots Weaver's (1919 *b*) system was adopted.

I am very much indebted to my senior students for their willing assistance in carrying out most of the anatomical researches from which these notes have been prepared. Among others, Mr. H. C. Bredell made an ecological study of the anatomy of grass roots, Mr. W. J. Stapelberg worked on the general anatomy of the roots of grasses, while Mr. J. J. Theron made an intensive anatomical study of *Themeda triandra* Forsk. I am, however, responsible for the general plan and initiation of the various researches, which I have also supervised and directed throughout.

Grass Roots and their Tissues.

Roots of grasses arise endogenously from the stelar tissues. Priestley and Radcliffe (1924) suggests that the endogenous origin of roots can be explained by the fact that the water and the nutrients which are necessary for rapid growth are confined to the xylem and phloem, from where they are distributed. This explanation is supported by the fact that grass roots are only formed when the water supply in the soil is adequate.

The development of the root was studied, but was found to present nothing new, and need therefore not be repeated.

The innermost of the primary cortical initial cells, which are destined to become the endodermis, retain the power to divide tangentially longest, so that some of the cells of the endodermis a little distance behind the growth point may still form a tangential wall. The radial arrangement of the cortical cells and the formation of tangential walls in the endodermis

give the impression that this tissue has been formed from a cambium. Undoubtedly this has led Henrici (1929) to interpret it erroneously as a cambium.

The exodermis, which is generally a more or less clearly defined layer of cells in grass roots, is formed from the primary layer of cells immediately below that from which the epiblem is formed. The succeeding layer of primary cells divides by means of oblique walls to form the sclerenchyma tissue. In grass roots with a soft and early deciduous cortex this tissue is one layer thick, while in those with a harder persistent cortex we find that, by irregular division in the region of maximum growth in thickness, 2 to 5 or more layers of small elongated cells are formed. They fit so closely that no intercellular spaces are formed. From the remaining layers of primary cells the actual cortical tissue is formed, which more or less retains a radial placement. As has been pointed out before, the endodermis develops from the innermost layer of primary initial cells of the cortex, and remains one layer of cells thick. Occasionally, however, a tangential wall may be formed during the development of the tissues, by which another layer of cells is added to the cortex.

The Root Cap.—In the grass root it is also a conspicuous apical structure which can often be made out by the unaided eye. When young it is pale yellow in colour, but as it advances in age it becomes darker until it can ultimately be seen as a dark speck at the root tip.

In the young stage the cells of the root cap of grasses are more or less rectangular, but towards the outside they are more or less spherical with the walls also very much thickened. The thickening is not pure cellulose, for it is only faintly coloured with chlorzinc iodine, and neither is it dissolved by cuprammonia. After a treatment with Eau de Javelle it stains bright red in Congo Red. If treated with a strong $Cu.SO_4$ solution, followed by 50 per cent. KOH, it becomes blue. Ruthenium red also stains these walls. All these reactions show this thickening to consist of a mucilaginous substance. Protein is, however, also stained red by Congo Red, but this substance does not give the reactions for protein with Millon's reagent nor the Xanthoprotein reaction, showing that it cannot be an albuminous substance. Furthermore, these walls expand when placed in water and shrink in absolute alcohol, which is further proof that it is a mucilaginous substance very closely related to cellulose. When the cell wall expands the whole cell also increases in size, from which we conclude that the primary wall is also made up of this mucilaginous material, which is apparently formed by the protoplasm of the cells and deposited on the primary wall. The protoplasm of these cells is also coloured a deeper red in Congo Red than that of ordinary meristematic cells, showing that mucilage must be present and has subsequently developed.

For the greater part the root cap is separated from the root apex by a layer of mucilage of the same consistency as the cell walls. This layer is rather thick in *Anthephora pubescens* Nees. It also extends along the root to where the root hairs appear (0·5 cm. from the apex). In some grasses (e.g. *Cymbopogon marginatus* (Hack.) Stapf, *C. plurinodis* Stapf, and *Hyparrhenia hirta* (Linn.) Stapf) it occurs up to 3 cm. from the apex, while in others (e.g. *Anthephora pubescens* Nees, *Sporobolus fimbriatus* Nees, *Themeda triandra* Forsk., and *Panicum coloratum* Linn.) it is found up to 10 cm. from the apex.

The mucilage is not only a product of the root cap, but also of the epiblem as Duggar (1911) suggests, for the contents of these cells are coloured a deeper red in Congo Red than those of the underlying cells. In the case of *Anthephora pubescens*, when epiblem cells and root hairs die, the cells do not lose their contents, which forms a coagulated mass that also takes on a red colour with Congo Red.

The Cortex.—In the grasses examined it was found that the development of the root apex more or less remained constant, but differences were observed in the differentiation of the tissues. As in the case of leaves among the vegetative parts the cortex appears to be the most variable part of the root. With the exception of the pith the stele exhibits the least variations. This is also what we would expect, for the cortex is more closely connected with the soil and, consequently, also with the variations which it exhibits.

The cortex consists of several clearly marked tissues, viz. (*a*) epiblem, (*b*) exodermis, (*c*) sclerenchyma, (*d*) true cortex, and (*e*) endodermis, which are dealt with separately.

Epiblem.—The epiblem cells of grass roots varies very little in shape and size. Their outer free tangential walls are always arched out, and fit closely as well as against the exodermis, so that hardly any intercellular spaces are met with.

The cortical tissues of most roots die off sooner or later, and at the same time the protoplasmic content also disappears. In a young stage the cell contents of the epiblem stain a deeper red in Congo Red than those of the rest of the cortex.

In the annuals which were studied (e.g. *Tragus racemosus* All., *Aristida adscencionis* Linn., *Digitaria ternata* (Hochst.) Stapf, and *D. sanguinalis* Scop.), as well as in the perennials of moist habitats (e.g. *Eragrostis plana* Nees, *Cynodon dactylon* Pers., *Paspalum dilatatum* Poir., and *Hyparrhenia hirta* (Linn.) Stapf, etc.), the mucilage occurs up to 2 cm. from the root tip. In more xerophytic grasses (e.g. *Themeda triandra* Forsk., *Sporobolus fimbriatus* Nees, *Panicum coloratum* Linn., *Anthephora pubescens*, etc.) it occurs a greater distance from the root apex. In the case of *Anthephora*

pubescens, which usually grows on sandy places, this mucilage layer is rather thick and often occurs over the whole length of the root. In *Rhynchelytrum roseum* (Nees) Stapf and Hubb., which grows usually in stony localities, the mucilage occurs up to 10 cm. from the apex, but it is readily soluble in water, forming a gelatinous solution.

Warming (1925) points out that the grasses of the Egyptian desert (e.g. *Aristida* spp., *Andropogon* spp., *Elyonurus* spp., *Panicum* spp., and *Sporobolus* spp.) possess a thick sheath of sand particles round their roots, and, furthermore, that these particles are embedded in a mucilaginous substance excreted by the root hairs. He maintains that this sand sheath serves as a protection against a loss of water from the root into the soil when the latter becomes dried out. Weaver (1919 *a*) and Henrici (1929) have also noticed that the grass roots which still possess their cortex are enveloped by a soil sheath, a fact which they ascribe to the root hairs holding the soil particles between them. The roots of the local grasses also exhibit this sheath, but it appears as if the particles are not held by the root hairs only. The grasses with many and long root hairs (e.g. *Brachiaria serrata* (Thunb.) Stapf and *Eragrostis* spp.) also have a thick soil sheath, the soil adhering to the epiblem and the root hairs projecting through it. It becomes more apparent in those grasses with fewer root hairs and with a thicker mucilage layer on the roots (e.g. *Anthephora pubescens* and *Themeda triandra*). Here it is quite evident that the soil particles adhere to the outer surface of the mucilage layer.

Although this mucilage can absorb much water and expand greatly, it, however, does not dissolve in water, so that the roots which are placed in water still possess it after several days. Even in boiling water it dissolves very slowly. The mucilage may become a hard, insoluble, corky layer. In *Anthephora pubescens* two layers are very clearly discernible: the inner layer swells in water and is stained red by Congo Red, while the outer layer is hardly stained and does not swell. It is in this outer layer that the soil particles are embedded. In *Sporobolus fimbriatus*, *Triraphis andropogonoides* (Steud.) Phill., and often, too, in *Panicum coloratum* this suberisation is still more evident. The roots of these grasses are a reddish-brown colour caused by the suberisation of a thick layer of the mucilage. This is very resistant to the action of H_2SO_4, and is only slightly stained red in a hot solution of Sudan III. When this condition is reached almost all the root hairs have broken off. It is also evident that some of the particles of soil adhere to the root hairs.

We agree with Warming (1925) that this mucilage functions as a protection against the loss of water into the soil. This becomes evident in grasses like *Sporobolus fimbriatus* and *Triraphis andropogonoides*, where it forms a hard outer layer. In young roots it may assist in the absorption of water.

Root Hairs.—As these are fully dealt with in a previous paper (Goossens and Stapelberg, 1933), it is only necessary to give a summary here. They occur over the whole length of the roots of the grasses examined by us. They do not develop to the same extent in all the grasses, some having a large number which may be long, and others having far less or very much shorter root hairs. They may also persist for years. Under moist conditions the root hairs develop very readily. Heat also seems to affect their development, usually resulting in the formation of cone-shaped masses of root hairs.

Exodermis.—In the grass roots examined, the layer of cells directly below the epiblem is usually clearly marked off from the surrounding tissues. This layer of cells corresponds with the exodermis which is found

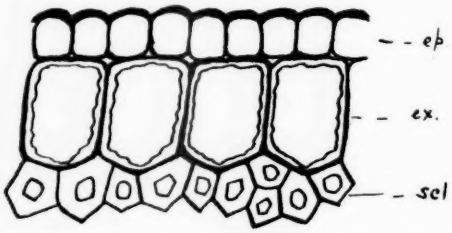

FIG. 1.—T.S. of the root of *Panicum coloratum* Linn., showing the epiblem (*ep.*), the exodermis (*ex.*) and sclerenchyma (*scl.*).

in the roots of most Monocotyledons. In *Panicum coloratum* it consists of large cells which fit closely (fig. 1). In the other grasses examined the elements of this layer are smaller, but because they do not break away from the sclerenchyma they are easily distinguished.

When first developed the cells of the exodermis are all similar in shape and form, but when elongation of the root takes place some of them remain shorter than the others. Scott (1928) and Goebel (1922) also distinguish between the long and short cells in the exodermis. In the early stages all the cells are thin-walled and of cellulose, but as they advance in age the walls are thickened. In the first instance a material of a fatty nature is deposited on the original wall. The cell wall no longer shows cellulose reactions and is stained red in Sudan III, which shows that it is a suberin substance. This suberin layer is formed on all the walls of the long cells. Later, a second layer is formed. This second layer, which consists of cellulose, is often so impregnated with lignin that it gives very weak cellulose reactions. Scott (1928) and Goebel (1922) have found that a secondary suberin lamella developed on the long cells. In the grasses examined by us, the short cells, which are named "passage

cells," were devoid of a suberin lamella, and even the secondary cellulose lamella on the inner tangential and the radial walls was very poorly developed. On the outer tangential walls, however, the cellulose lamella is thick and dome-shaped. The same phenomenon was observed by Francke (Scott, 1928) in the exodermis of certain of the Asclepiadaceae.

The suberin lamella may also be formed in some of the epiblem cells (e.g. *Setaria nigrirostris* Dur. and Schinz., and *Sporobolus fimbriatus*), but it is usually much thinner than in the cells of the exodermis. In the former grass a few of the sclerenchyma cells bounding on the exodermis may also possess a thin suberin layer, and in this case the cell walls are but slightly lignified. In this grass the cellulose lamella is well formed and can be well studied. In cross-sections of fresh roots this layer is stained slightly by Phloroglucin and HCl, and yellow in Analin sulphate, showing that it also contains lignin. If the sections are at first treated with Chromic acid, followed directly by Eau de Javelle, it is stained violet when transferred to chlorozinc iodine. During this treatment the lamella does not become dissolved. However, the lignin is removed from the ground material by the oxidising agents. This ground substance in the first instance is deposited as a cellulose lamella which gradually becomes impregnated with lignin. This impregnation with lignin probably takes place very early, for this lamella gives cellulose reactions only in the early stages. In the grasses with an early deciduous cortex the cellulose lamella is very poorly developed, and in some cases (e.g. *Sporobolus fimbriatus* and *Rhynchelytrum roseum*) it is not discernible at all.

Most macerating solutions like Eau de Javelle, Schulzë's macerating solution, and Chromic acid attack the cortex first and the cells become separated from one another, while the epiblem and exodermis are still held together. It is only after the sections are boiled for a short while in Schulzë's macerating solution, or in Chromic acid, and immediately placed in Eau de Javelle that the epiblem and exodermis are separated from one another. Very often the exodermis cells then still remain attached to each other. These reagents attack the middle lamella but do not dissolve the suberin quickly. From this we may conclude that the suberin has also been embedded in the middle lamella.

If the sections are heated in KOH the exodermis becomes disintegrated into separate cells. Whereas suberin is readily attacked and dissolved by KOH it proves that the suberin is present in the middle lamella. As a matter of fact the greater part of the suberin reactions are weak. After a treatment with KOH the cells are very much enlarged, for the suberin swells while the cellulose lamella draws away from the suberin lamella.

The Endodermis.—The endodermis varies a great deal as far as the shape and the thickness of the tertiary cellulose lamella are concerned.

These differences are very clear in the different genera, but as far as the grasses studied are concerned, it remains remarkably constant in each genus. In *Sporobolus*, for instance, this cellulose lamella on the inner tangential walls is very thick, almost filling the entire cell lumen (fig. 2). In *Brachiaria* again, the endodermis cells are large with a thick cellulose lamella on the inner tangential walls only.

As in the exodermis, there are long and short cells. While the cells are increasing in length, the cell walls show cellulose reactions, but on reaching their full size a secondary suberin lamella is formed which at first becomes evident on the radial walls, and shortly afterwards also on

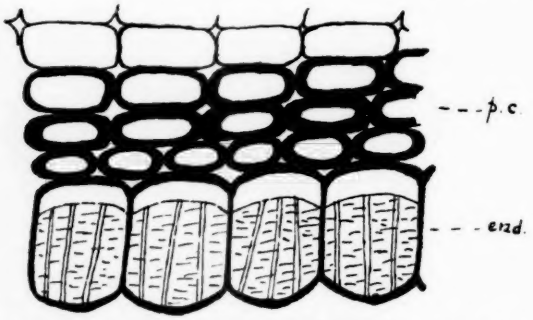

FIG. 2.—A portion of the root of *Sporobolus fimbriatus* Nees, showing the thickened persistent cortex (*p.c.*) and the endodermis (*end.*).

the other walls. This layer when heated stains a deep red in alcoholic Sudan III. This suberin layer is resistant to strong mineral acids. If sections are placed in strong H_2SO_4 the cellulose and lignin are very soon destroyed and the cells become disintegrated, leaving the endodermis as a complete cylinder round the stele. It can then be clearly seen that the suberin lamella has been deposited on all the walls. Even when sections are boiled in strong Chromic acid the endodermis is not affected.

Priestley and Radcliffe (1924), in a discussion of the Casparian strip on the radial walls of the endodermis of Ferns, maintain that this strip consists of the original cellulose wall, impregnated with lignin, and that a suberin lamella is deposited on the primary walls of the cells during secondary thickening. Scott (1928) also mentions the presence of a Casparian strip in the long cells of the endodermis of *Funkia ovata*. The short cells of the endodermis of this plant, according to him, have not got these strips, and therefore remain passage cells. He furthermore maintains that the Casparian strip in this plant consists of suberin and not of lignin. In the endodermis of grass roots nothing was found to correspond with

the Casparian strip of the Filicales or *Funkia ovata*. It can be assumed that the Casparian strip does not develop at all in the endodermis of grasses, but that the endodermis at once passes over to the secondary stage with a suberin lamella on the inside of the primary walls. Suberin is deposited in both the short and long cells as in the case of the secondary endodermis of Ferns.

Almost simultaneously with the suberin lamella a tertiary lamella develops. In *Brachiaria serrata*, *Rhynchelytrum roseum*, and *Digitaria Pentzii* Stent (commonly known as the Potchefstroom Fingergrass) this tertiary lamella is rather thick on the inner tangential walls, but very thin on the radial and outer tangential walls. Sometimes it is hardly visible. In *Anthephora pubescens* the outer tangential walls are also thickened, but not so much as the inner walls. The radial walls, too, remain unthickened. The tertiary lamellae on the tangential walls are always perforated by pits, which go right up to the suberin lamella. In *Cymbopogon plurinodis*, *C. marginatus*, and *Hyparrhenia hirta* a few large pits also occur on the inner tangential walls.

The tertiary lamella is usually impregnated with lignin. With Phloroglucin and Analin sulphate it gives lignin reactions. If the sections are first placed in Chromic acid and then treated with Eau de Javelle to remove the lignin, the lamella is stained violet in ClZnI, showing that it contains cellulose. The same results are obtained with Schulzë's macerating solution.

In the endodermis of *Sporobolus fimbriatus* and of *Panicum coloratum* it can be seen that the tertiary lamella is made up of the following distinct layers:—

(i) The part bordering on the suberin lamella and going right round the cell. This layer swells in ClZnI, and is also stained a violet colour (fig. 3, A and B).

(ii) An inner layer of the lamella on the inner tangential walls which swells much less in ClZnI, and is not coloured violet, but retains the light yellow colour of lignin. This part of the lamella also clearly shows striations.

From this it can be concluded that the tertiary lamella is deposited as a cellulose layer against the suberin lamella right round the cells. After that, layers of a substance, which is probably a mixture of cellulose and lignin, are deposited on the inner tangential walls. In those grasses which do not show these two layers in the tertiary lamella, this cellulose layer is impregnated with lignin from the beginning.

As we have seen, the endodermis consists of long and short cells, in all of which a secondary suberin lamella develops. This, as well as the tertiary cellulose lamella impregnated with lignin, makes it unlikely that the short

cells in grasses should be considered as "passage" cells. As this lamella is thickest on the inner tangential walls, hardly any water would pass, except through the pits. As no "passage" cells are left, the suberin lamella would very much reduce the flow of water from the stele to the cortex and *vice versa*. The absorption of water being confined to the young apices, it appears that the endodermis with the secondary and the tertiary lamellae have assumed the secondary function of isolating the stele from the cortex. This secondary function seems to be rendered necessary as a means of protection against a loss of water, for the cortex

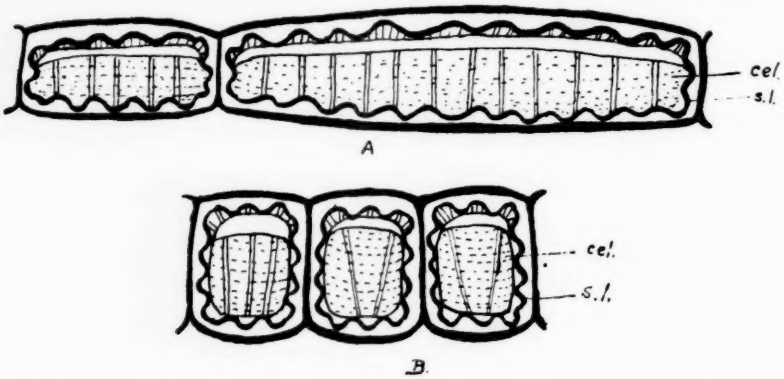

FIG. 3.—Side view (A) and cross-section (B) of the endodermis cells of *Setaria nigrirostris* (Nees) Dur. and Schinz. showing the sinuated suberin lamella (*s.l.*) and the cellulose lamella (*cel.*) on the inner tangential walls.

of grasses always contains air spaces which function as a sort of äerenchyma into which water from the stele could easily escape.

Sclerenchyma.—The sclerenchyma, which appears in the roots of most grasses, is a mechanical tissue. It consists of one or several layers of cells directly under the exodermis, and may persist through the whole life of the roots. This sclerenchymatous layer is absent in some of the grasses of dry localities (e.g. *Anthephora pubescens*, *Rhynchelytrum roseum*, etc.). Other grasses (e.g. *Eragrostis plana*, *Setaria nigrirostris*, etc.) which have a persistent cortex have sclerenchymatous tissue of several layers which have no intercellular spaces. Where this tissue is well developed, it was often found that the thickening of these cells commences 0·5 cm. from the apex. The cell walls are clearly stratified.

Where the sclerenchyma is absent or remains undifferentiated (e.g. *Anthephora pubescens*, *Rhynchelytrum roseum*, etc.) the cortex soon becomes compressed and dies. This dead cortex subsequently becomes loose

and crumbles away, leaving the bare stele surrounded by the endodermis. It was found that these roots lose their cortex as the soil becomes dry.

In the grasses where the sclerenchyma is several layers thick, the cortex lives much longer and is not soon compressed. In *Eragrostis plana*, *Paspalum dilatatum*, *Setaria nigrirostris*, etc., it remains alive as long as the roots live, and in some cases (e.g. *Eragrostis plana*, *E. superba*, etc.) it apparently persists for one or two seasons. In the latter it has often been found that, although all the connections between the stele and the sclerenchyma have been broken, the cortex still persists as a dead sheath round the central cylinder.

It was found that the sclerenchyma is best developed in roots of drier than of more hydrophytic localities. On the other hand when the xerophytic grasses (e.g. *Anthephora pubescens*, *Rhynchelytrum roseum*, etc.), in which sclerenchyma is not differentiated, are grown in soil of which the water content was kept above 20 per cent. throughout, no sclerenchyma is developed.

Temperature also seems to have an influence on the development of the sclerenchyma, for it was found that the roots formed in summer are harder than those formed during winter.

The Cortex.—It is usually characterised by the radial placement of the cells as if they had been formed from a cambium. The walls of these cells usually remain unthickened, but in *Setaria nigrirostris* they become thickened more or less at the same time as the sclerenchyma cells. Very often even the cell walls which have broken up and remain strung as septa between the endodermis and exodermis are thickened. During summer the thickened cell walls of the cortex of this grass show lignin reactions, but with the advent of winter they give weak cellulose reactions.

The layers of cells of the true cortex bounding on the endodermis differ from the rest. In all the grass roots examined there was usually at least one layer of cells next to the endodermis which did not break up in the formation of the air spaces. Even when the whole cortex crumbled up, this layer of cells persisted. In *Eragrostris plana*, *E. superba*, *Rhynchelytrum roseum*, *Anthephora pubescens*, etc., these layers of cells remain unthickened. In *Panicum coloratum* and other *Panicum* spp. there were always two or more layers of cells which did not break up. In these cases the inner tangential walls of these cells were much thickened, while the radial and outer tangential walls remained unthickened. The lumen of these cells is very small and situated towards the outer tangential walls (fig. 4). The thickening is striated. Many pits also occur in the thickened walls, giving the cells of these layers the appearance of typical endodermis cells. In these grasses the endodermis consequently appears to be made up of more than one layer.

In *Sporobolus indicus* R.Br., and *S. fimbriatus* Nees, three or four layers of cells persist round the endodermis (fig. 5). These cells have both the

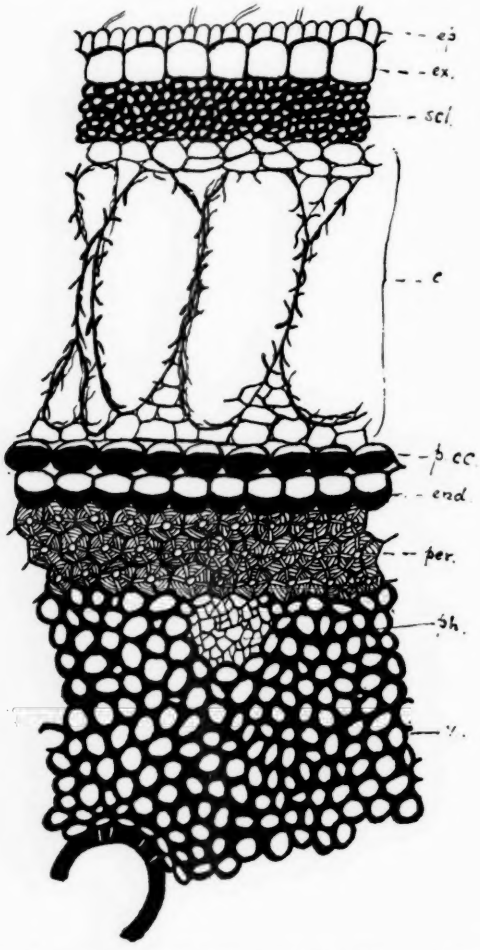

FIG. 4.—Portion of a cross-section of *Panicum coloratum* Linn. *ep.*, epiblem; *ex.*, exodermis; *scl.*, sclerenchyma; *c.*, cortex; *p.cc.*, persistent cortical cells round the endodermis (*end.*); *per.*, pericycle; *ph.*, phloem; *x.*, xylem.

inner and outer tangential walls very much thickened, often to such an extent that the cell lumen is altogether suppressed. The thickening layer

is also striated and possesses pits; this thickening consists of lignin. The cells of the first and second layer next to the endodermis contain a suberin lamella as in the case of the endodermis and exodermis.

Henrici (1929) has observed that these layers of cells differed from the other cortical cells, and thinks that they developed when the cortex became perforated. She maintains that in *Cymbopogon plurinodis*, *Sporobolus fimbriatus*, and *Anthephora pubescens* the outer tangential walls are

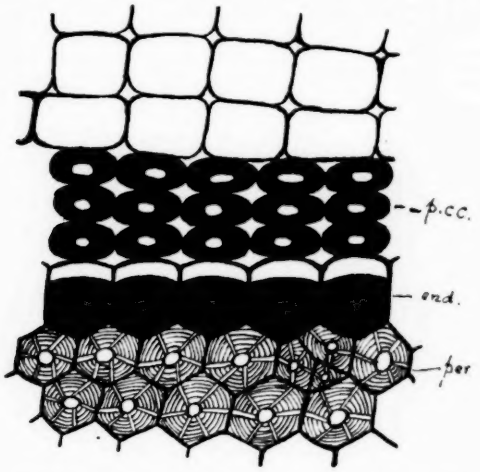

FIG. 5.—Section of the root of *Sporobolus fimbriatus* Nees, showing the pericycle (*per.*), the endodermis (*end.*) with the thick cellulose lamella on the inner tangential wall, and the thickened persistent layers of the cortex (*p.cc.*).

thickened, and that here and there a cell remains unthickened, thus corresponding with the "passage" cells, which she describes in the endodermis. No "passage" cells were found in the endodermis of the local grass roots, and the inner tangential walls and not the outer were found to be thickened. Henrici also expresses the view that the persistent layer of cells round the endodermis becomes meristematic and forms a new or perforated cortex within the old one. She therefore compares it with a phellogen, and apparently uses this to explain the presence of "a second layer of cortex cells" on the outside of the "cortex." It seems quite clear that by "a second layer of cortex cells" is meant the lignified sclerenchyma, exodermis, and epiblem, and the "cortex" which she refers to is the two or three layers of persistent cortex cells round the endodermis which may be no longer united to the former by means of septa (e.g. *Eragrostis superba* and *Paspalum dilatatum*).

Like Goebel (1922) she considers the sclerenchyma in grass roots to be a velamen. According to her discussion of *Brachiaria nigropedata* (Munro) Stapf, the persistent layer of the true cortex, viz. of the thin-walled parenchyma on the inside of the sclerenchyma layer, would then be the exodermis, while the "two layers of small cells" (sclerenchyma) together with the "two layers of large cells" (exodermis and epiblem) would form the velamen. It should be borne in mind that the outer layer of cells still possess root hairs, which together with the structure and arrangement of the cortical tissues makes the analogy with a velamen unfeasible.

The most important feature of the parenchymatous cortex of grass roots is the development of air spaces which run like air passages more or less through the whole length of the root (fig. 6). Henrici (1929) studied the development of these spaces in *Phalaris bulbosa* Linn. and *Paspalum dilatatum*, while Dunn (1928) has investigated it in the seedlings of mealies and wheat. The result arrived at in the study of the local grasses more or less agrees with those of Henrici and Dunn.

According to the formation and development of these spaces, grass roots can be divided into the following two classes:—

(1) The roots with a well-perforated cortex and with regularly formed air spaces (e.g. *Eragrostis plana*, *Paspalum dilatatum*, *Setaria nigrirostris*, *Panicum* spp., etc.). The development of the air spaces in this class of root is very well illustrated in *Eragrostis plana*. Two or three millimetres from the apex the cortex is made up of layers of radially placed isodiametric cells which are more or less equal in size. Two centimetres from the apex radial spaces begin to develop between the radial rows of parenchyma cells of the cortex. Afterwards a few of the cells adjoining the spaces burst open on the free side. The bursting is soon continued to neighbouring cells. In this way the radial spaces increase in size. Close to the root neck the cortex cells were found to be broken up to such an extent that the endodermis and the sclerenchyma are only connected by the old broken cell walls which appear like strings across the space round the stele (fig. 6). The one to two layers of cells round the endodermis, however, do not break up.

(2) The roots have few and small air spaces in the cortex, which develop more or less irregularly (e.g. *Anthephora pubescens*, *Rhynchelytrum roseum*, *Digitaria Pentzii*, *Themeda triandra*, *Triraphis andropogonoides*, etc.). The first stages of air space development in these roots are the same as in the case of the previous class, the only differences being their irregular development and small size. Here the radial rows of cells do not break up, but only certain cells inside the parenchymatous cortex tissue. Usually certain of the cells of the three or four central layers increase in size and break up to form air spaces.

The moisture content of the soil apparently determines whether the spaces will develop like in the first or in the latter class. The grasses which developed roots during a period when the moisture content of the

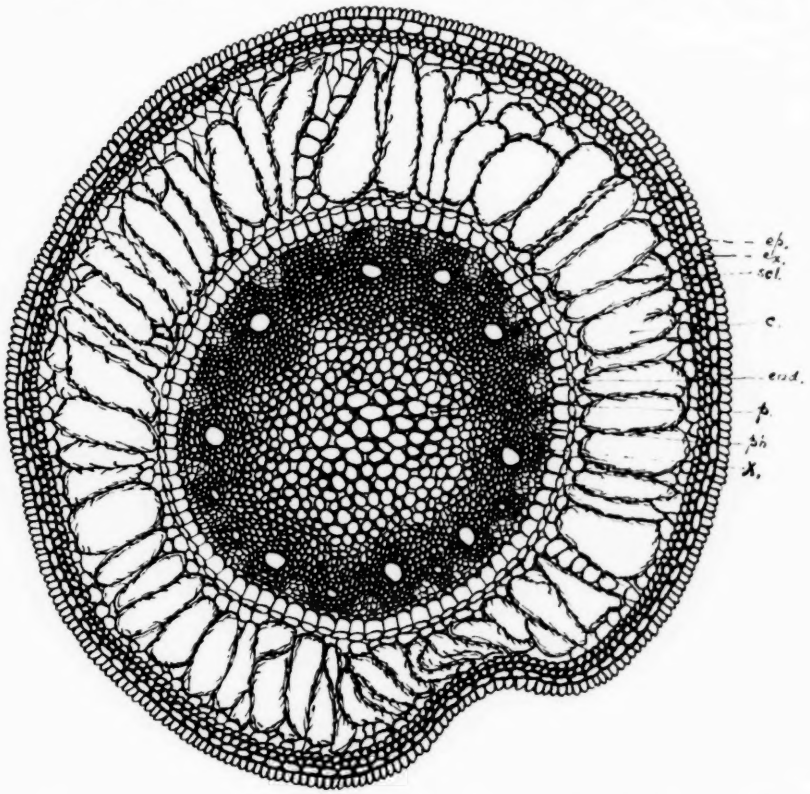

FIG. 6.—Cross-section of the root of *Eragrostis plana* Nees, 10 cm. from the apex. *ep.*, epiblem; *ex.*, exodermis; *scl.*, sclerenchyma; *c.*, cortex (perforated); *end.*, endodermis; *x.*, xylem; *p.*, pith; *ph.*, phloem.

soil was high had large and almost regular air spaces, but as the moisture content decreased fewer and smaller spaces were developed. *Cymbopogon marginatus* and *C. plurinodis* are the best examples of intermediate stages.

In both classes the air spaces usually appeared a day or two after the newly formed roots have emerged. Where the roots have developed in watery solutions and have grown rapidly (2 cm. in 24 hours), the air

spaces were formed up to 2 cm. from the apex, while in the soil, where growth in length was very much slower, they occurred up to 1 cm. from the apex, and were also much smaller. During dry periods small spaces were found up to 0·5 cm. from the apex.

From water-culture experiments it appears that none of the essential elements nor the pH of the solutions had any influence on the development of these spaces. Dunn (1928) has found similar results in well-controlled water-culture experiments.

It was found that when *Anthephora pubescens* was grown in watery solutions the roots which were formed in summer had relatively larger air spaces. Those formed in the beginning of April had smaller spaces, while those formed in winter had not developed any. It is important to note those roots with the smallest air spaces were the first to turn brown and suffocate. The same was found in the water-culture plants of *Sporobolus indicus*. In both cases the roots which died as a result of apparent suffocation were found to be devoid of air spaces, while the summer roots with large spaces kept alive.

The soil-culture plants of *Anthephora pubescens* had larger or smaller spaces during summer, depending on a larger or smaller moisture content, while the winter roots had no spaces in the cortex. Dunn (1928) has found similar results with *Triticum vulgare*, but Henrici (1929) thinks that a "loose cortex tissue" may develop at any season of the year, as long as the moisture content is not too low. Henrici (1929) has also shown that the South African grasses require a larger oxygen supply in order to grow well.

Dunn (1928) has pointed out that the perforated cortex probably serves as an äerenchyma. Henrici (1929), however, thinks that although in grass roots the perforated cortex may have a secondary function of providing oxygen, it primarily serves as a water-storing tissue. She has observed that grasses with a persistent cortex were the first to show growth, and that after a drought of ten months *Eragrostis superba* was the only grass at Armoedsvlakte to have developed new leaves. Furthermore, she contends that grass roots with a loose cortex never become so dry as others, and that the perforated cortex acts as a sponge out of which water could be squeezed before and after rain. Although it is possible that the grasses with a persistent cortex are not so dry as others it is doubtful whether water is stored by the cortex. It probably protects the stele from losing water. It was observed that in grasses with a soft cortex (e.g. *Anthephora pubescens*, *Eragrostis superba*, etc.) it may act like a sponge for the absorption of water. When the roots of these grasses were suspended in a beaker of water so that the tips only were submerged, water ascended along the inside of the perforated cortex for a considerable

distance. The cortex in these cases was dead, so the water could not have been taken in osmotically. From this it appears that a soft cortex readily absorbs water from which the active growth region can draw.

Warming (1925) mentions that in the case of Egyptian desert grasses the persisting ground sheath protects the roots from a loss of water. This, however, does not mean that the perforated cortex acts as a water-storing organ, but merely that it protects the stele from losing water. If this

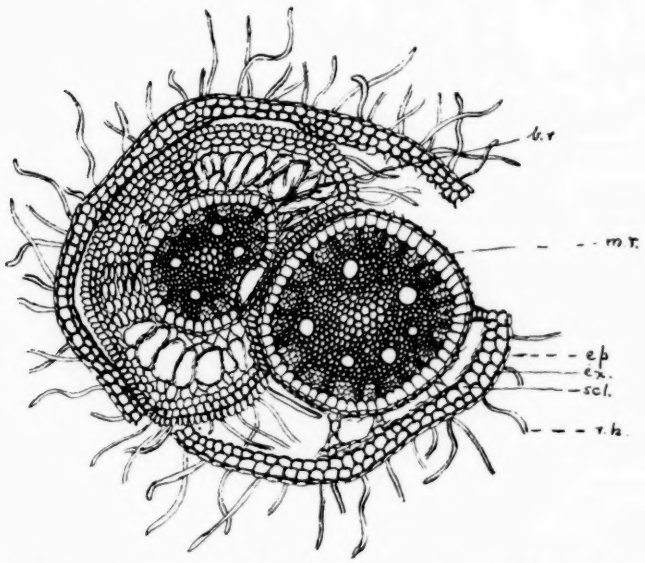

FIG. 7.—Cross-section of the root of *Pogonarthria squarrosa* Pilg., showing two steles within a common cortex. *m.r.*, main root; *b.r.*, branch root; *r.h.*, root hairs; *ep.*, epidermis; *ex.*, exodermis; *scl.*, sclerenchyma.

cortex stores water, as Henrici (1929) maintains, it would lose it readily through the persisting root hairs which usually die soon. Furthermore, the cortex of the roots of grasses of arid regions, which require a greater supply of water, usually breaks up and disintegrates soon. As Henrici admits herself, grass roots have the best developed perforated cortex during the wet growing season when a high water supply is not so much in demand.

In *Pogonarthria squarrosa* Pilg. a very interesting feature was observed. In local specimens of this grass two steles were found in a common cortex. Henrici (1929) has found a similar feature in this grass at Armoedsvlakte.

Although the two steles were enclosed by a common cortex, it was found that the enclosed one was surrounded by its own cortex, which even possessed its own root hairs (fig. 7). It was found that *P. squarrosa* formed branch roots close to the base of the roots. Very often the branch root does not penetrate the perforated cortex but grows down one of the air spaces in the mother-cortex, resulting in two steles in an apparent single common cortex.

Another interesting feature also occurred in *Anthephora pubescens*. A plant of this grass with a root of which the apex was not injured, was planted in a watery solution. After the root had elongated for a short distance it split into two equal branches. From successive microtome sections it appeared that the group of apical initial cells had split into two, each of which carried on the elongation of the root independently, with the result that two equal branches were formed dichotomously. Caldwell (1930) describes a similar phenomenon for the main root of *Lycopersicum esculentum* Mill.

Summary.

1. The roots of grasses arise endogenously.

2. The root cap is an apical structure of all grass roots. Its cell walls and cell content are of a mucilaginous nature. To a great extent a mucilage layer also separates the root cap from the root apex.

3. The epiblem cells of grass roots are usually fairly uniform in size and shape. Mucilage is usually associated with the epiblem in which soil particles become embedded, forming a protective sheath.

4. Root hairs usually occur over the whole length of grass roots, and may persist for several years. Their growth takes place at the apex, where they become cemented to the soil particles, together with which they form a soil sheath. Their development depends on the moisture content of the soil and on the temperature.

5. An exodermis is found in grass roots of which the cells are at first all similar in shape and form, but as the root elongates they become differentiated into long and short cells. All the walls of the short cells except the outer tangential walls remain unthickened.

6. A well-marked endodermis separates the cortex from the stele. It varies much as far as the shape and thickness of the tertiary cellulose lamella is concerned. When the cells have reached their full size a secondary suberin lamella is formed. No Casparian strips were observed in the endodermis of grass roots, but a suberin lamella is developed on the inside of the primary walls. There are, therefore, no passage cells left. The endodermis consequently functions as an isolating sheath round the stele.

7. The roots of most grasses have a well-developed lignified sclerenchyma, which probably lends support to the perforated cortex. Its development is apparently affected by the moisture content of the soil and by temperature. In some xerophytic grasses there is no sclerenchyma, the cortex remaining soft. Grass roots are therefore either hard or soft.

8. The cortical tissues which usually become perforated in grasses are characterised by isodiametric and radially placed cells. The walls of young cells usually consist of cellulose, but soon become lignified. Newly formed cells usually contain much protoplasm, which generally decreases and disappears as the cells advance in age. One or more of the layers of cells bounding on the endodermis usually persist. The walls of these cells very often become thickened.

9. A perforated cortex is generally present in grass roots and seem to be associated with an efficient oxygen supply. The following types of roots were recognised: (i) those with a well-perforated cortex, of which the air spaces are regularly formed; and (ii) those with a few and small perforations which develop irregularly.

10. In the case of *Pogonarthria squarrosa* two steles were observed in a common cortex, a branch root having grown down one of the air spaces. In *Anthephora pubescens* a root was found which appeared to be dichotomously branched as a result of a division of the apical initial cells.

11. The stele was studied but was found to be of the usual monocotyledonous type with very little variation. During winter the pith cells are packed with starch grains.

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THE ARCHAEOLOGY OF CERTAIN PREHISTORIC SETTLEMENTS IN THE HEILBRON AREA.

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(Communicated by Professor R. A. Dart.)

(With Plates I–IV and seven Text-figures.)

(Read April 18, 1934. Revised MS. received June 14, 1934.)

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1. Introduction.

This chapter of South African archaeology is new, and it has therefore been thought necessary to prefix a short explanation of the terms used in the paper.

Settlement: A collection of dry stone-built enclosures within a restricted area, and of a similar period of occupation.

Kraal: A large dry stone-built enclosure which may have been a yard to an attached smaller enclosure, or a cattle-yard: hence the use of the South African term "kraal."

Enclosure: A more or less circular dry stone-built wall, the enclosed space being of varying diameter, the whole intended originally to surround a hut of wattle and daub.

Beehive or beehive hut: A stone-built hut, roofed by cantilevering or corbelling in thinner stones.

My attention was first directed to the ruined, dry stone-built settlements of the Heilbron area by Mr. Lomax of that town, who for many years has shown a keen interest in the various remains of the district, and who sent me several potsherds (red and black burnished, and with triangular patterns) of a type that I had learned previously to associate with the Khami Ruins in Southern Rhodesia. Further specimens were obtained during 1929 and 1930, but it was not until August 1931 that I was able personally to inspect the sites, when a rapid inspection was made of the sites Vechtkop, Willowglen, and Krugerskraal. Sufficient evidence was obtained to indicate their outstanding importance. It was, however, most unfortunate that a dozen complete pot burials, beaconed in readiness for my visit, were wantonly dug out and both pots and burials destroyed.

A generous offer by the Rand Daily Mail to finance a small investigation removed any difficulties, and, with the assistance of Messrs. Boxall and Sargent, who lent cars, a party of nine persons was transported to Heilbron, where sixteen boys were hired. The party consisted of Messrs. Boxall, Glathaar, and Hendry (Surveyors), Mr. Giles (Mining Engineer), L. H. Wells, M.Sc. (Physical Anthropologist), N. L. Murray, B.Sc. (Photographer), all of the Witwatersrand University, and Messrs. Sargent (who kindly acted as cook), Hulme (Press), and myself. To all of these first-mentioned thanks are due for a strenuous week-end's work, and to Messrs. P. de Kock and Molendorf for allowing the investigation to take place on their lands, and to Mr. Moore for much assistance in transport and overseeing. The plan of proceedings was to survey the main sites, obtain as much material as possible for investigating from certain middens, and to ascertain, if possible, the relative age and chronological sequence, if any, of the various types of stone-built settlement.

2. General Description of Locality.

The Heilbron sites are situated about 80 miles south of Johannesburg. The farm Krugerskraal is situated south-west from Heilbron on a low ridge, which can be traced eastward for some miles until it turns almost at right angles, and, steadily increasing in height, it continues to the farm Willowglen, a distance in all of about 14 miles. The whole ridge is covered with ruins, which are visible from the plain. From the highest point at Willowglen an extensive panorama is viewed stretching from Kopjes, about 36

miles distant to the south-west, to Gottenburg, about 30 miles distant to the north. Below the highest point of the ridge, which forms a spur, are the settlements on the farm Jamaica, which lies between Willowglen and the Rhenoster River. Across the river are small kraals, probably of a later date. At the other end of the ridge at Krugerskraal the presence of the Rhenoster River appears to have been the deciding factor in the choice of site. From the highest point on that farm, Krugerskraal, ruins of stone-walled settlements with their middens are found all the way along the ridge, to within a few yards of the river bank. The site is many hundreds of times larger than the Vechtkop or Tafelkop sites, and must always have been a centre of considerable importance. It was not possible to examine more than a small portion of the remains in detail, and those were chosen because of outstanding appearances, and the obvious facts of superposition of sites or occupations.

During delay in the preparation of this paper two plane table surveys have been mislaid. I believe, however, that the description is sufficiently clear to prevent that loss having any serious effect upon the argument.

3. Description of Sites.

A. *Willowglen Site.*—The first Willowglen site examined was that on the top of the spur. The whole area is a tumbled mass of unroofed oval hut enclosures, stone-roofed beehive huts, and fragments of dilapidated stone pathways which have been partially buried beneath ash-heaps of later date. The original settlement (Willowglen I) is buried beneath many feet of accumulated débris from smaller contracted occupation sites (Willowglen II), while its middens remain on the periphery. The main features of Willowglen II are the stone-roofed beehive huts, lack of settled plan, and general untidiness.

The outlying Willowglen II stone-roofed huts are numerous, and it is difficult to apportion them to individual settlements. There is an irregular mass of huts around hut No. 5. Two small huts overlie the foundations of one of earlier and larger type, which, with other foundations formed an early settlement. These smaller huts have double foundations, the outer face of the wall is vertical while the inner is corbelled.

Many of the outlying beehive huts are larger than usual, being about 7 feet in diameter. The method of building is the same, but the inner walls are not drawn in so rapidly. It is uncertain whether these are earlier or later in construction than the smaller huts. The architecture of Willowglen II is strongly suggestive of long-continued occupation—sufficiently long to have allowed of change in building habit.

Much stone building has taken place in this area during the post-

Moselekatse period (Plate II, fig. 4), which is characterised by the presence of doors and windows, but there is no evidence whatsoever to suggest that the corbelling, or half-corbelling, was ever employed during that period.

In the upper, later (contracted?) occupation-midden were found fragments of a skeleton and two infant pot burials—one found at surface level, the other at a depth of 2½ feet. Otherwise the middens trenched on this area produced nothing but crude potsherds. Cylindrical ivory beads have been found in the past by the proprietor and since lost. These middens differed from all the others examined in the inordinate number of stones which were mingled with the débris. This accumulation of stones can only have come from the dilapidation of older habitations. Superficially on the mounds, but probably thrown up by the activities of meercats, was found one cowrie charm. The outlying middens, certainly not connected with the later (contracted?) occupations, produced a pottery of a better type, with added moulded bands, but free from other ornamentation. They are of a characteristic dull black and evenly burned.

This site would undoubtedly repay careful excavation, but the work would be extensive and necessarily expensive.

B.—Between Willowglen and Jamaica is a small dilapidated settlement, the stones from which were utilised for building square shelters several feet high during the Anglo-Boer War (Plate II, fig. 4). These buildings have been built within kraal areas and in part over middens, and it is a tribute to the strategy with which these ancient sites were occupied that they were reoccupied in this fashion in recent times. The two small middens of this site are only a few yards in circumference and from 1 to 2 feet in depth. They produced a collection of imported glass beads, imported bottle glass from which fine artefacts had been produced, fragments of a gin jar and two fragments of what appear to be modern oriental ware; while superficially were found brass cartridge cases (R ↑ L C 11), trouser buttons, screws, and wire.

A third and larger midden alongside these bead-bearing middens has a circular platform of flat stones built over it. It is about 8 feet in diameter and has not a surrounding wall of stone. Time was insufficient to permit a trench being driven through this mound. The surroundings were much disturbed by meercats, and, as in the previously described midden, the surface was strewn with wire and cartridge relics of the Boer War period, but it contained native pottery.

C. *Jamaica Site.*—The Jamaica site shows a compact group of hut enclosures with many isolated outlying huts. A large number of these hut-enclosing walls have been destroyed for the building of a now vacated and dilapidated farmhouse. There is good, easily quarried stone in this neighbourhood (*cf.* Zimbabwe method), hence the Jamaica walling has a

good appearance, almost that of dressed stone. Several of the stone-roofed huts are connected with walls, and the entrances of some lead into the courtyard, while others lead outwards. The huts are of the type of construction already described. Kraal entrances are *narrow*, not more than 2 feet wide, and the side-posts are made from single large blocks of rock of suitable shape. On one part of the site there are huts between an inner and an outer wall. The whole plan can no longer be traced, but remnants suggest the Riet River arrangement (3).

Deeply grooved millstones were found within the courtyard area, and two types of hone stone—one with deep narrow grooves triangular on section for points, and the other with long, broad shallow grooves used for blades such as assegais. On the floor of a hut were found haematite pebbles, potsherds of large vessels of the beer-pot type, with the squared lip and everted rim so characteristic of these sites, also a stone pounder or clay preparer, identical in shape and size with clay pounders obtained by me from living Hottentots and Namaqualand sites. The middens produced a portion of one small drinking-pot, many sherds of the everted-rim type, the vertical-necked pots, but not a single fragment of patterned pottery, although all were of Bantu facies.

To the Jamaica side of the river there are a number of small structures varying in plan, and ranging from the recent European use of stones gathered from old sites to the prehistoric, which of course may mean only about a century to a century and a half ago for the end of their occupation. In each site (fig. 2) there is a combination of cattle enclosures and hut, the latter being stone-roofed and of small diameter, and also of the larger dimensions with no stone roof. Middens are not noticeable in their vicinity, but being small, and situated on a hillside, they probably have been washed away. The walls of the cattle enclosures are low in nearly all cases.

D. *Krugerskraal Site.*—The buildings on the farm Krugerskraal were in good repair until recently. Even the present proprietor admits having removed tons of stones for building kraals. Here again, on a long narrow strip of veld, are numerous stone-walled enclosures and settlements in ruins. Those nearer the homestead were examined in some detail. These will be described first.

Site D presents many peculiar and interesting features. It consists of a central courtyard which is surrounded by seven oval vertically walled hut enclosures, each measuring 15 by 20 feet. The surfaces of the door-posts show an even patination and lack the smooth polished areas due to rubbing —a feature so frequently seen in the other sites.

The courtyard presents a clean surface free from ash or débris. Unlike the sloping surrounding veld, it is level. Its floor is formed of fine gravel

stamped or trodden hard. To achieve this levelness the ground is built up against the upper foundation wall of the hut on the downhill side. This indicates that the courtyard floor was laid down after the foundation walls had been built.

From the two huts flanking the entrance to the courtyard two diverging walls extend outwards and terminate in two small guard huts. The floor of the entrance and entrance passage thus formed is roughly cobbled. This paving is continued within the courtyard as far as the entrance of the first hut on the left side.

In one of the larger huts was found a fine circular and centrally placed hearth built of stones laid flat, with a border of stones placed at right angles to hold the whole in good position and to form a kerb (Plate II, fig. 6).

On this site three circular clay furnace hearths were found, on and near which were slag, vitrified stones, and lumps of clay burned red as though by a fierce fire. These lumps of clay are presumably portions of the furnace wall. They show twig marks, suggesting that a wattle or wicker framework had been built to sustain the wet clay until it was baked to form the furnace wall. Five small circular stone-paved areas lay in the neighbourhood of the furnace sites. In some cases short-paved pathways led to them. These I thought at first must have been used for stacking of ore or the breaking of ore, but in no instance was anything found in the immediate neighbourhood to suggest that, nor are any of the stone surfaces battered or injured as one would expect if they had been put to that use. Their positions, removed from the furnace sites, suggest that they are the foundations of clay granaries such as are commonly used by the more northerly Bantu tribes.

A large and well-made pathway to the north-east of this site (Plate I, 4) is bordered like the hearth, with flat stones placed vertically. The cattle enclosure adjoins the courtyard and forms part of the walls, and though the survey shows the entrance to be from within, I cannot remember seeing any well-defined entrance, and consider the position shown doubtful.

On the courtyard surface were found two fragments of a soap-stone pipe decorated with incised lines.

The surrounding middens produced two unusual sherds. One is the base of an amphora-like jar (Plate IV, 6), the "stumpy leg" of Lowe; this type of pot is still favoured by certain tribes of the more northerly east coast. The other is a base which may be described as a truncated amphora base; another such base, but splayed, has been found near Koffiefontein (Witwatersrand Med. School Mus.). In the middens the incomplete baked clay object shown in Plate III, fig. 2, 6, which I believe to represent a phallus, was also found.

Site C shows an architecture similar to Site B but in a much more

dilapidated condition. The huts are of the large massive foundation type, surrounding a courtyard. Within the area of this courtyard there are two granary platforms and the remains of pathways. Comparison with the other sites suggests that it is unlikely that such structures could be located within a courtyard area. It may therefore be presumed that they belong to a subsequent occupation. Within the courtyard area there were also found three pot burials, which will be discussed later.

Site D lies 800 yards to the south-west of Sites B and C, and covers a slight rise in the ground, the highest point of which is still only a few inches below the courtyard, but the limits of the hillock have been much extended circumferentially by ash deposit during the successive occupations. The central portion of this area, the original courtyard, is now converted into a modern cattle kraal. The courtyard is situated on the apex of the hillock, and a trial pit in the centre disclosed rock at a depth of a few inches. The remains of the surrounding huts are of the larger type, with massive foundations most of which have been utilised in the building of the modern kraal. The knoll had been chosen deliberately for the site of the settlement. The levelling of the courtyard has given a sunken appearance to the inner walls of the huts. This site is therefore comparable with Site B, and on it and its middens have been built smaller and later huts.

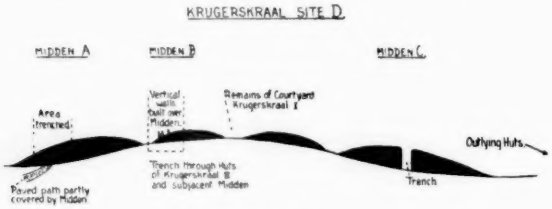
Site D has thus been used during more than one occupation. Here again the survey does not show all the remains, some of which are recognisable as foundations only after the most careful scrutiny. The survey shows the remains of a settlement with outlying huts. This is partly covered by middens and partly by a later occupation site of smaller area. A broad, paved, well-made pathway covered by the huge midden A (text-fig.1) suggests the presence of a third and earlier occupation site. This midden does not belong to the latest occupation, the huts of which are themselves in part built on midden, but to an intermediate one. There is no paved way that could belong to the later occupation, and clay furnace sites were not found.

The lower and earlier occupation huts have double foundations of massive stones (text-fig. 2), with about 8 inches space between the two rings, giving a wall width of 3 feet 6 inches. They are in part covered by midden A. The huts are probably those of the pathway builders. To the south-west of Site D and not marked on the survey, because it was noticed too late, is a single small, paved granary platform. A peculiar structure suggesting a crucible furnace was found on this site in the huts or circles marked 2 on the survey. These huts have been built over midden material, into which their walls do not extend.

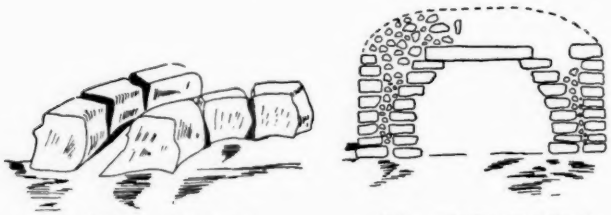
At the junction of the walls of the two enclosures was a circular pit 14 inches in diameter. It had been doubtfully paved or filled with small stones which rested on ash, and has a stone-lintelled entrance of 6 by 8

inches leading into the enclosure interior. None of the stones showed signs of fire, and no suggestive relics were found in or around it. The pit was roughly built of undressed stone. A mammillated sherd was found superficially near here, and to the west, lying on the surface of the midden, was found a duckbill scraper.

There was a large, paved platform built on midden A similar to the platform of Willowglen II. It has no relation to the fragment of earlier



TEXT-FIG. 1.


Massive Foundations at First Period at Krugerskraal (K I).
Lighter construction and corbelling at later period at Vechtkop (V II).

TEXT-FIG. 2. *Cf.* Lowe, *loc. cit.*, pl. v, 1, 2, and 3, and text-fig. 1.

paved way that survives in its vicinity. The platform is built on a considerable depth of ash, forming a small knoll. The proprietor remarked that he had removed the paving stones, the upper surfaces of which were "highly polished," for building purposes. There were five small holes on the platform, which the owner explained by stating that in each of them had stood a monolith, the sagittal axes of which were placed radially. This suggests support to a superstructure rather than any ritual significance. The platform is surrounded by a stone wall, the foundations of which do not extend to any depth into the ash. In the ash beneath were found bones, and pottery of the unornamental type, well made, and in one instance with a beautiful red burnish. Except for this one sherd the evidence obtained was inconclusive and disappointing.

Four trenches were cut through the middens of Krugerskraal, Site D

(text-fig. 1). Trenches 1 and 2 were cut through midden C, trench 3 through midden A, and trench 4 through midden B. The following objects were obtained from these trenches:—

Trench 1 produced three cowrie charms; a bronze ring and portion of a second from ground level (about 3 feet); an unbaked clay model of a Wildebeeste cow, 3·2 cm. long and 3·4 cm. high, well modelled, and not to be mistaken for an Afrikander cow (Plate III, 2) (two other fragmentary models, probably of oxen, have since been found in the middens of another site near by); and also fragments of a skeleton of a young child.

Trench 2 produced fragments of two ivory beads, similar to those found and since lost at Willowglen.

Trench 3 yielded teeth of zebra and hippopotamus and a grave of a child.

Trench 4 yielded only potsherds.

Between middens A and B was an area of a few feet of original hill surface. Trench 4 commenced on this, and was driven through midden ash and the overlying hut-circle. The lower ash was distinctly stratified and coarse. Between trenches 1, 2 and 3, 4 are traces of large massive hut foundations of the earliest stratum of D.

In trench 1 (midden C) there was absolutely no stratification. It was of the same consistency from top to ground level 3 to 4 feet beneath, where a thin pink layer was found. The same can be said concerning trench 3 (midden A). Trench 4 (midden B) produced a section as follows:—

(*a*) 4 to 8 inches ash and earth.
(*b*) 3 inches grey ash.
(*c*) 4 inches light yellowish grey ash. A furnace layer?.
(*d*) 3 inches grey ash.
(*e*) 4 to 5 inches pinkish ash.
(*f*) 3 inches grey ash.
(*g*) 2 inches ashy earth, pink admixture burned clay?. Rock surface.

A comparison of the ash from the three middens proved of interest. The ash from 1 was softer and more floury to the feel than was that of any stratum of 4, which is obviously an old deposit. It is reasonable to suppose, and I believe that the supposition is confirmed by observation of camp fires and other ash-heaps, that time and the elements have consolidated this midden.

The Krugerskraal sites, therefore, show an early occupation represented by the ruins of Site C. This may be referred to as Krugerskraal I, *a*. Sufficient has been shown to indicate that this was not the only occupation, but that similar large huts of massive foundation were built at a later period, represented by Site B and probably the earliest of D (Krugers-

kraal I, *b*). These were the large open or thatched hut occupations, accompanied by pathways and metal working. On Site D the remains of this occupation are covered by the middens of a later one, Krugerskraal II. A third and still later occupation (Krugerskraal III), degenerate in all respects but overlying an earlier and better stad, is present on Site D.

Continuing from Krugerskraal towards the Rhenoster River are successively the remains of a courtyard type of settlement with large hut-circles or enclosures; the surrounding subsidiary huts have all fallen in. Among the débris was found a lower millstone, in which the groove had been worn to a depth of 3 inches. At a distance of a quarter of a mile from E is another small site, G, almost rectangular, rounded corners, with an inner dividing wall and an outer hut-circle. After this is an enormous ash-heap 60 yards in length overwhelming a settlement of early type (H), in the centre of which are later constructions (H 2). This latter was certainly occupied for more than thirty years. After a short gap another huge ash-heap appears. Two hundred yards farther on is another settlement of early type (I), very dilapidated; and then half a mile farther on is the river, the clay from which no doubt provided the material for pot-making and furnace-building, and the bush and water of which no doubt dictated the choice of site to the metal-working community. From this description it would appear that the earlier settlements were fairly regularly distributed along the ridge, and this stresses the idea that the second occupation, restricted and degenerate, was preceded by some catastrophe, pestilence, or massacre.

E. *Vechtkop Site.*—This site, described by Lowe after his superficial examination (1), was visited three times by our party for purposes of comparison. Lowe's description of the layout of the buildings is accurate, but his "preliminary" account of the construction of the huts was found to be incomplete. This matter will be discussed in detail in the section on Architecture. The finds made by us comprised a small iron mining gad (see Plate III), two bone awls, a sherd of a small Bantu drinking-pot with incised and almost compartmented ornamentation, crude, thin, and suggestive, as far as the ornamentation goes, of Bushman influence. The other sherds gathered were mostly coarse, but included one deliberately ribbed sherd of good texture and a large, heavy coarse fragment with impressed herring-bone pattern (Plate IV, fig. 8, 4).

On returning from the site a human bone was picked up on the hillside, outside a meercat hole. After removing a quantity of ash and a number of fragments of heavy, thick, well-burned clay slabs (furnace walls?), a series of stones placed vertically in the gravel surface of the hill and forming an oval cist was found. Within this, in contracted posture, was the very decomposed remains of an adult skeleton. The vertebral column could be traced only by the mass of roots that had consumed it. The

skeleton was situated directly on the clean gravel surface of the hill, lying on its left side, head to the north-west, and facing more or less to the east. Everything indicated that the burial had taken place previous to the deposition of the ash midden. So far I have found no record of any such other cist burial in South Africa. It is not comparable with the Riet River burials (3), or with Bantu or Hottentot burials (4). The skull must have been sharply flexed on the body, for the space was small, but careful search revealed not even the remains of a tooth.

An important difference between this site and those near Heilbron is the absence at Vechtkop of stone constructions overlying earlier middens. This indicates that all the remains seen on the surface belong to one period. The finding of a pre-midden interment, however, demonstrates that at this site there are two periods of occupation. These may be distinguished as Vechtkop I and Vechtkop II.

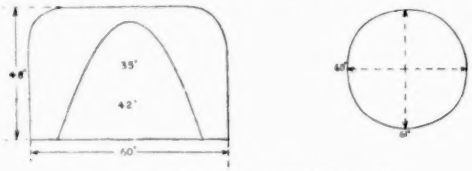
Detailed Description of Huts and Enclosures.

(a) *Early Period.*—The character of the stone structures of this period are best seen at Krugerskraal, where it is represented by Sites B, C, and D (period, Krugerskraal I). The settlements of this period are small, consisting of 6 to 8 huts. The hut enclosures are built around a courtyard carefully levelled and beaten hard. At Site B the entrance to the courtyard is splayed and flanked by small guard huts, and its surface is cobbled (Plate I, 5). Cobbled pathways bordered by rows of flat stones set on edge are also a feature of these sites (Plate I, 4). Small granary platforms, paved with flat flags, and sometimes served by short lengths of pathway, are situated outside the hut or stad. The kraals are also external to the courtyard.

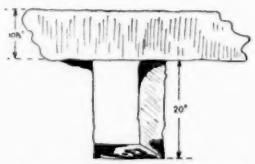
Typical hut enclosures of this period have double-ring foundations of massive stone blocks (Plate I, 6). The stones flanking the doors are particularly massive. Mr. Giles estimated the weight of an average block at half a ton. The construction therefore borders on the megalithic. At Site D these door-posts are polished by friction of constant coming and going out; at Site C this polish has been removed by the action of the elements. The internal dimensions of the huts are 20 by 12 feet. One hut at Site B possessed the fine-paved and bordered circular central hearth shown in Plate II, 6; otherwise there was no trace of internal fittings. At Site D, the entrance of the principal hut, which faced outwards, was screened by a right-angled fence of upright slabs. A similar outwork is present in front of the door of the principal hut at the contemporary Site H 1.

It is evident that the hut enclosures of this period had foundations of stone, and the huts may have been of clay or wattle-work in part, and their

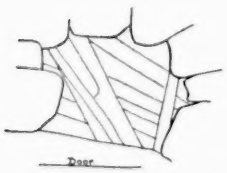
roofs certainly of thatch. The obvious habit of reusing material by later settlers on the site would account for the disappearance of wall stones and the survival only of massive foundations. It is not possible to associate definitely any stone-roofed huts with this period. If they existed it was probably as outlying huts and not as part of the main hut-circle. This



Diagrams of form and dimensions of typical Vechtkop Huts



Typical entrance and lintel (Vechtkop).



View of under-side of roof of Hut (Vechtkop).

TEXT-FIG. 3.

period may therefore be called the Pre-Beehive Period, and is typified by Krugerskraal I.

(b) *Later Period.*—This period is characterised by the predominance of the stone-roofed huts. This type has been found with variations of grouping at Willowglen, Jamaica, and Vechtkop. As the latter site was made the basis of Lowe's preliminary description of this type of architecture, it may be first of all discussed.

Doorways are usually made of single boulders or slabs as figured by Lowe, but now and then they, as well as the walls, may consist of double layers. The walls in every hut examined on all sites were built double, and on double foundations (see Plate I, 2, and text-fig. 2). The method of

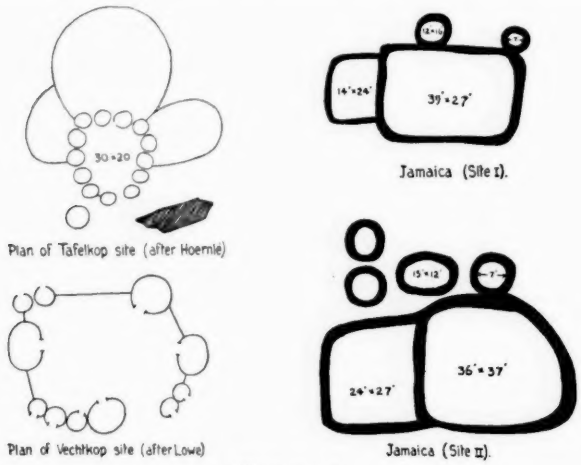
building requires a more detailed description. The smaller beehive huts of an internal height of 3 to 4 feet have a single boulder 15 inches high for either door-post, and a single large flat stone for lintel. These huts average 7 feet in diameter. The larger beehive huts are 8 feet in diameter, 5 feet in internal height, with doorways 2 feet 6 inches in breadth, 18 inches high, and 2 feet in depth, and their side-posts are built up of three or more stones, and seemingly the stone nearest to hand was used for the job. The walls have a double foundation consisting of two concentric circles of large boulders. The inner wall is thus quite separate from the outer, and the inner and outer walls are often built up independently of one another. When the inner wall of the Vechtkop huts had reached a sufficient height, after slight inward corbelling, the roof was completed by adding three or four large slabs of rock. This of course saved the builders the most difficult part of the corbelling. The interspace between the inner and outer walls was then filled in with rubble, the outer wall being continued almost *vertically* upwards for about 3 feet, the amount of batter being variable within small limits, and the whole was then finished by the piling on of small stone (see Plate I, 3). In no instance on this or other sites are the outer walls corbelled, nor do they possess a batter due to any other method of building.

Lowe's plan of a typical settlement shows both huts and kraals incorporated into the enclosure wall, the former usually opening outwards, the latter invariably inwards. Isolated huts also occur. A variant type is a single hut attached to the circumference of a small kraal. In one case (discovered by Mr. N. L. Murray) the hut possessed, in addition to the normal external entrance, a rear door 12 by 12 inches opening into a right-angled passage or tunnel between the hut wall and the kraal wall, and communicating with the exterior through an unusually low and narrow orifice.

The size of the blocks employed is sometimes very considerable. Lowe observes that the door lintels are the largest stones, and estimates that some may attain a weight of 500 lb. One specimen encountered by us, however, has an estimated weight of 1700 lb. This is easily the largest block seen by us on any of these sites, but on the whole the stones employed in the latter buildings are smaller and more manageable than those in the earlier foundations.

The huts at Willowglen are similar in construction to those at Vechtkop. As at that site, larger and smaller examples are met with. A partly collapsed specimen was sectioned to bring out the points of the structure. Plate I, 1, shows its state before the sectioning, and Plate I, 2, the appearance at the close. This hut has a lintel measuring 17 by 32 by 3 inches, and has also a stone threshold; the entrance is 24 inches high, 18 inches wide

below and 25 inches above. The outside wall is vertical for 4 feet, and the domed roof is formed of loose small stones. Inside, the inner wall is corbelled from the first courses at ground level. It will therefore be seen that the inner wall forms an inverted bowl, while the outer wall forms a ring, and the space between is filled with rubble. An unusual feature in this hut was the presence of a paved floor formed of large flat stones at the periphery, and of smaller stones towards the centre, where there were traces of fire,



TEXT-FIG. 4.

but a piece of tin found in the ash suggests that these huts have been used as shelter quite recently. The roofing stones were 29 by 12 by 2 inches dimensions, indicating once again that in the Vechtkop manner corbelling was not carried out to the roof top. The wall was sectioned, and in the rubble core traces were found of a clay or dagga filling, in which were a few potsherds. In three other instances a similar filling was found in hut walls here or at Jamaica, so that it may be safely concluded that at one period at least a dagga mortar was in use. In this hut the door-posts, in contrast to the rest of the wall thickness, are formed of a single thickness (Plate II, 3).

At Jamaica, in spite of later reconstructions, it is still possible to make out the plan of a ring of huts attached to the enclosure wall, but facing outwards. It is possible that in this case there was an outer ring-wall, but this is not usual in these sites.

One hut on this site was excavated. The external sides are vertical for between 3 and 4 feet, the entrance is about 2 feet in height, the lintel

is supported by three wall courses, the walls are 2 to 2½ feet in thickness, the roof, which is 5 feet high at the centre, is formed by corbelling twelve courses and then placing large slabs over, these in turn being covered with rubble. The floor is of clay and has a diameter of about 8 feet. At Jamaica and Willowglen the wall courses are carefully laid with "through stones" placed so as to pass through the thickness of the wall, and to some extent bind the two layers together. These wall courses are therefore unique so far in the Union, in that binding is usually absent from these dry stone structures, where huts and connecting walls simply abut against one another. This is in conformity with the observations of Miss Caton-Thompson (18) on the Rhodesian structures.

The sites on the opposite bank of the river facing Jamaica have a single hut situated in contiguity with, but outside, an enclosure. These are comparable with the single-hut kraals already noted at Vechtkop. Other examples of this type of layout have been observed among the later settlements at Krugerskraal.

At Krugerskraal the stone-roofed huts are in a much poorer state of preservation than at the sites previously considered. All are more or less completely collapsed. The surviving foundations show the double ring of stones (Plate II, 5); the floor is of hard clay or earth, which sometimes rests upon earlier midden deposits.

5. Analysis of the Architecture.

From a survey of the findings of previous investigations of stone structure in South Africa, together with the findings at Heilbron, the following types of architectural units emerge:—

(*a*) The courtyard type settlement, large diameter (15 × 20 feet), stone-walled enclosures for huts of wattle and daub and associated with small granary platforms, hearth furnaces, paved pathways with vertical stone borders (site: Krugerskraal B—Period, K 1).

(*b*) Courtyard settlement, including both thatched-hut enclosures and stone-roofed huts in the settlement area.

(*c*) Courtyard settlement, all huts stone roofed, they and the kraals built around a central courtyard (site: Tafelkop).

(*d*) The courtyard (?) type with hut enclosures containing beehive huts described by Anderson, as occurring in the Marico District. The illustration is suggestive of a *cluster* (11).

(*e*) Two circular walls, the inner forming a kraal with huts between the inner and outer walls. Huts probably of thatched-roof type in stone-walled enclosure (sites: Riet River, Aasvogelkop, Johannesburg).

(*f*) Similar to (*e*) but with stone-roofed huts attached to the kraal wall (site: Jamaica II).

(*g*) Kraal settlement. Huts with entrances to outside around a centrally situated kraal (site: Vechtkop).

(*h*) Single huts: one or two stone huts situated outside a small stone-built kraal, which contains one or more dividing walls (site: Aasvogelkop?). These are undoubtedly linked up with the small Jamaica types.

(*i*) Independent: small kraal, one side formed by krantz with a single hut external to it and unattached (site: Aasvogelkop, N. slopes).

(*j*) Clustered stone-roofed huts (sites: Tafelkop, Willowglen).

It is not possible as yet to assign positions in chronological order to all the types of settlements recognised, nor can they all be stated to belong to the same people.

The outstanding point on these Heilbron sites is the number of settlements. It would be valuable to know if they were deserted after the death of an inhabitant. If so, this would shorten the period required for the building of so many, but would still not account for the occupation of previously inhabited sites, unless the reasons for removal had been long forgotten. Nor has a hut or hut-circle been found with a rear hole that would suggest the orthodox Bantu method of removal of the dead. It would, however, be extremely difficult to make such a hole in a stone-roofed hut without causing the collapse of the whole structure (*cf.* Hoernlé's remarks on enlargement of entrance at Tafelkop). The tunnel-like rear entrance noted in one Vechtkop hut would never have been intended for such a purpose. The fact of the survival of the early type of settlement as at Krugerskraal B, H, and I, almost uninterfered with, is probably due to the fact that at no time was the population in any one area ever great, or the number of inhabited settlements many. The re-use of building material during the latter occupation is un-Bantu like, and provides a further suggestion that at this period some other element had come to the fore.

Already some light is shed on the life that went on in and around these stone-built settlements. The kraal walls are nowhere of sufficient height to protect the stock from animals or man, though there may have been originally a second stage of non-permanent material. Isolated hut enclosures and kraals are common: nowhere is there any sign of fortification, and there is no evidence on any of the sites examined to suggest that doorways were protected by means of closure with stones or boulders. This suggests immunity from attack. Everything points to the earlier periods of occupation having been peaceful and prosperous. The inhabitants did not possess cattle, for no kraal entrance is wide enough to admit, nor walls

high enough to restrain, them. The kraals were either for sheep or goats.

6. Description of Associated Cultures and Customs.

(a) *Burial Customs.*—Thirteen pot burials and four interments were encountered during the excavation of these sites, two of which were adults. One of these was the Vechtkop cist-grave, already described, the other was an interment in an outlying midden at Krugerskraal. This last is asserted by Mr. Molendorf to have been an adult pot burial. It was one of those wantonly destroyed before my arrival. The hole from which a large pot and an adult skeleton undoubtedly came is not large enough to contain both except the one be within the other. He stated that a chunk of metal was found with the bones, and that he replaced this. The fact was known to a few people, and speculation as to whether the metal was or was not gold probably was the starting-point of the vandalism.

Two interments of children were also found at Krugerskraal. The remains of a child in a very fragmentary condition were recovered from trench 1. In this case, curiously enough, there was neither a covering pot nor any trace of surrounding or covering stones; nor was there anything that could be regarded as grave furniture. The other interment was that of a child of about eleven years, found in trench 3. In this case the skeleton, which was complete and well preserved, rested on the ground surface at the base of the midden. It was disposed in the foetal position, lying on the left side and facing the east. The grave was sealed by two large flat stones placed a few inches above the skeleton, and about 2 feet below the surface of the midden heap. Once again there was no trace of grave furniture. This skeleton is of later date than the commencement of the midden, probably later than the midden.

These four interments show a remarkable variety in burial customs. The two best preserved burials, the Vechtkop "cist-grave" and the burial of the elder child at Krugerskraal, show, however, identity in the posture and orientation of the corpse, though the structure of the tombs is widely different. The Vechtkop cist has, as has already been pointed out, no recorded parallel in South Africa. The Krugerskraal grave, on the other hand, shows both in the disposition of the body and in the covering slabs a close correspondence with Bush-Hottentot practice, more particularly with that of the "Strandlooping" peoples of the southern coastal area (FitzSimons, 39; Péringuey, 40). Burial in the seated posture, which is extremely rare in the coastal area, becomes more common among the Bush peoples towards the north-west (Dornan, 12), probably as a result of Bush-Bantu intermingling.

Among the Bantu peoples burial in the sitting posture appears to be

the rule. The literature of the subject is richer in vague generalisations than in definite statements. For the Bechuana peoples, however, Dornan (*loc. cit.*) is sufficiently definite, and recent inquiry has shown that this was also the primitive practice of the Zulu and Pondo peoples. In the location and construction of graves there is considerable local variation. Midden burial is not usual among the modern Bantu, but has been recorded from the ancient sites of Tafelkop (Hoernlé and Hoernlé, 1930) and Roodekraal (Laing and du Plessis, 1926).

Previous investigations have found burials associated with ancient stone buildings. Lowe and his co-workers at Vechtkop found skeletons in the contracted posture. At Tafelkop the Hoernlés found a seated skeleton with a pot inverted over the skull. The sitting posture recurs at the pre-Moselekatse occupation site of Roodekraal (Laing and du Plessis, 31), but at Blaauwheuvel in the Riet River Valley the skeletons lay on the right side, under elaborate superstructures as unusual as, though quite unlike, the Vechtkop cist.

Reason has been given for supposing that the Vechtkop cist-grave belongs to an earlier period than the remains reported by Lowe. The Krugerskraal burials, on the other hand, all appear to belong to the later phases of the history of that settlement. Thus the burial customs may be classified into three phases:—

I. *Early Period.*—Cist-graves (Vechtkop). There are no direct parallels of this type of burial in the Union. These are more likely to be discovered in Rhodesia, where developments in tomb building have occurred from an early period (Dart and del Grande, 41). The cist-grave was probably introduced into the Union by the first wave of Bantu migrations.

II. *Middle Period.*—The middle period is characterised by burials of Bush-Hottentot type, as exemplified at Krugerskraal, possibly at Vechtkop, which may have been introduced by intercourse with the south and west *via* the great river valley (*cf.* Blaauwheuvel graves).

III. *Late Period.*—This period shows the Bantu type of seated burials at Vechtkop, Tafelkop, and Roodekraal. This is likely a relic of the second wave of northern invaders (Leghoya or Bataung?).

Infant Pot Burials.—Apart from these four individuals and a number of others represented by finds of stray bones at Willowglen and Krugerskraal, all the other finds were of infants which had been buried in pots. Thirteen such pot burials were discovered, in addition to those destroyed before my arrival. With the exception of the three pots found in the courtyard of Site C at Krugerskraal all were buried in midden ash. Pot burials of infants in middens have also been recorded by Lowe at Vechtkop and by the Hoernlés at Tafelkop.

Two of the three pot burials found in the earth of the courtyard of Site C, Krugerskraal, were flattened and fragmentary, and their sherds were disintegrating. The third pot was complete though somewhat cracked. Its contents were earth, not ashes, as in the case of the midden burials. The infant bones in the complete pot had disappeared; all that remained was a small fragment of very friable animal bone, and the carefully arranged shroud of large potsherds and flat stones, which had taken up a position low in the pot after the decomposition of the corpse. There is no evidence to suggest that this was a midden burial, and that the pots remained after the midden had been washed away.

The majority of the pots found at Heilbron show signs of use on the fire, which usually caused the base to break; but the use of cracked pots for burials is not invariable—whole pots appear to have been used. In practically every case careful sherd covers had been provided, and in one case traces of powdered specularite (micaceous iron ore) adhered to these covering sherds.

Three pots contained an ostrich eggshell bead, in one case reddened with ochre. Bushmen, states Dornan (12), when they bury their women, add a few such beads. All the skeletons are those of new-born or premature infants. It is a common custom among the South African Bantu to bury remains of infants in pots. This applied both to infants killed for ritual or superstitious reasons, and to those which died naturally or were still-born. At the Heilbron sites pot burials of infants were more frequently encountered in the earlier than later middens. It may be inferred, then, that the late inhabitants did not practise ritualistic destruction of infants. If this is so, it suggests either the occupation of the site by people of different customs, or a degeneration of the customs of the original inhabitants, who presumably were Bantu. This supposition is strengthened by the fact that at Krugerskraal adult burials of the middle period are found in the later middens, in which pot burials are infrequent, although this may be an accidental circumstance. The earlier middens with their abundance of pot burials suggest that these pot burials belong to the early period and are therefore Bantu.

Unfortunately it is impossible to date accurately the pot burials of Site C. There have been no pot burials in this area since its visitation by Moselekatse. These are therefore at least one hundred years old. If they belonged to an old midden, then they are probably several hundred years old. The style of the complete pot does not suggest this, so its age remains for the present a mystery.

(b) *Cowries.*—Cowries, *Cypraea moneta* or *Cypraea annularis*, with the projecting dome ground down in order to produce an amulet that could be suspended from string, were found both at Krugerskraal and Willowglen.

All showed signs of much wear. This cowrie does not occur on the coast farther south than Madagascar's north point. This is the most southerly recorded find of these cowries, and considerably extends the limits shown by Jackson (32) on his map.

Similar cowrie charms were found by Miss Caton-Thompson at Chiwona (18, pl. xxix, Nos. 14 and 17), and among Bantu remains at Rooiberg (Dart, 42). Numbers of freshwater mussel-shells were found in superficial positions, also in roofed huts at Krugerskraal, Jamaica, and Willowglen. These occur so frequently in shelters of known Bushmen occupation that I believe their presence here to be due to the same people. No portion was found which showed signs of perforation for ornamental purposes.

(c) *Metal Work.*—(i) *Metal Working.*—No ore workings are known in the Heilbron district, although a heavily worn mining gad was found at Vechtkop. The only evidence of metal-smelting in the locality is the furnace hearths found at Site B, Krugerskraal, and they belong to the early period.

Three tuyères were found at Krugerskraal. All are of the same type as those obtained by Lowe from Vechtkop. They show a constriction of the tube 1 inch from the nipple end. From this constriction the tube widens out rapidly.

At Vechtkop, a site of the later period, crucibles for smelting metals have been found (Plate III, 4). There is no evidence, however, on this site of metals being smelted from the ores. The scarcity of iron objects on the Heilbron sites suggests that the metal was difficult to obtain, and that fragments of iron were melted down and reforged during later periods.

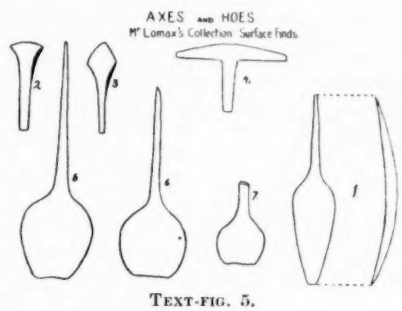
Professor Stanley of the Witwatersrand University kindly undertook the examination of the metals and slags found, and the following are his remarks:—

> "Under micro-examination the iron is of typical native manufacture, slag, carbon-free iron, and steel all being present in the sections. This indicates that a high proportion of charcoal was used in the smelting mixture, and also accounts, I think, for the small amount of iron in the slags. From a piece of the new lot of slag I have been able to extract a few small pieces of metallic iron, so no doubt they were derived from iron working. I forget whether I told you we found only 2 per cent. of iron (combined) in the previous slag examination and no metallic iron—possibly weathering in view of its very open spongy structure had resulted in oxidation of any free iron originally present.
>
> "The bronze is a real tin-copper alloy, and after cleaning by acid the surface exhibits characteristic fibrous structure, showing that it

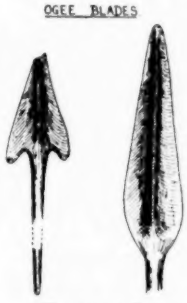
has been mechanically worked to shape. I have not yet examined it for evidence of annealing."

(ii) *Iron Objects.*—A flat-bladed iron strigil (Plate III, 1) with a curled tang was found on the surface at Site D, midden A. The modern Makalanga strigil illustrated by Bent (30, p. 46) is ridged ; otherwise the shapes are comparable. Strigils are usually flat-bladed, and the evidence afforded by this single instrument is too meagre to allow of argument that it represents the early flat blade (as opposed to ogee, text-fig. 6) technique of Zimbabwe.

A fragment of corroded assegai afforded no further information than that it was of native iron (Plate III, 2, 2). The iron mining gad from Vechtkop (Plate III, 1, 6) is similar in all respects to those from other mining sites in the Transvaal. Plate III, 5 shows the objects found on these sites,



TEXT-FIG. 5.



TEXT-FIG. 6.

now in private possession, especially in Mr. Lomax's collection : (1) is a hoe 21 inches long, with a greatest width of 4½ inches, and weighing 51 lb. 7 oz.; (2), (3), and (4) are axes: (2) is 8 inches long, 2½ inches in greatest width, and weighing 16 oz.; (3) is 9 inches long, with a blade 2¼ inches wide, and weighing 17 oz.; (4) is the blade of an axe similar to (3). The blades of these axes are deeply bevelled. (5) and (6) of the same plate III, 5 are two small blades found at Krugerskraal which have been identified as razors.

Three hoes were found of the same fan-bladed type. They varied greatly in length. A typical specimen is seen in Plate III, 3. Hoes form an important medium of currency and passed in trade from tribe to tribe (21). This might account for the variety of shapes found. (Text-fig. 5 shows a variety of hoes.)

(iii) *Bronze Objects.*—At Krugerskraal bronze rings were found in midden C. These correspond in technique to the iron rings found at

Chiwona, Southern Rhodesia (18, p. 126). This same technique is found in the copper or bronze bracelet from the Blaauwheuvel grave (Lowe, 1931).

(iv) *Whetstones.*—The whetstones are fragments of sandstone, usually about 5 inches in length. The groove is about 1 inch wide, and the striae are longitudinal, showing that the blades were sharpened by rubbing in their long axis. This suggests that the implements used were flat blades, notwithstanding the fact that the few iron implements found, with the exception of the strigil, were of the ogee technique.

(d) *Pottery.*—The thirteen pots found fall into two distinct classes: a well-made globular pot with a vertical short neck (found in outlying middens, *i.e.* the early pot), and a crude black vertical-sided pot of Bushman facies. Between the two is a degenerate type of Bantu pot, thick-walled, poorly finished, and with everted rim.

Lowe's stumpy pot leg, the amphora base, and splayed truncated amphora bases from Site B and Koffiefontein (Witwatersrand Eth. Museum), all suggest, as do the patterns, affinities with northern and eastern rather than western Bantu. There is a great variety of fragments showing marked divergencies in craftmanship and ornamentation. The general characteristics can, however, be listed under four heads:

I. Pottery bearing incised patterns (Plate IV and text-fig. 7).

(A) Colour burnish.

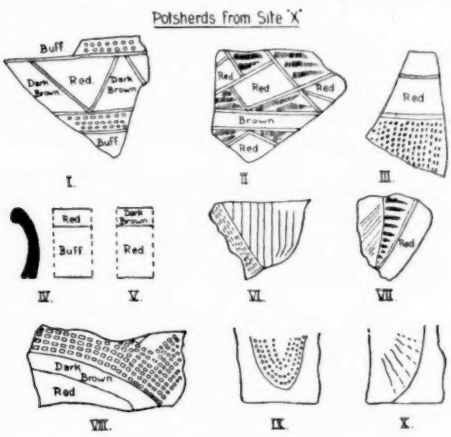
1. Black and red, in compartments.
2. A whole body burnished in red.
3. A whole body burnished in buff.

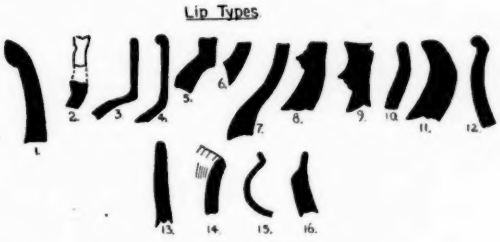
(B) Plain water burnish.

There are several beautiful developments that appear to be wholly localised in the pottery of this area, namely, combinations of (B) with brown, burnished stripes.

II. Non-burnished, black-bodied, coarse finish or medium finish, with appliqué-work bands round the neck. Occasionally vertical-applied work is found, and on one site (H 1) this vertical-applied work is combined with crude prick and incision ornamentation in patterns reminiscent of the leaf motif of earlier and finer burnished pottery. That this is an intermediate type of pottery is proved by its occurrence in later middens. One fragment of such ware was found in a late degenerate pot (Plate IV, 9 and text-fig. 7, VIII, IX).

III. Coarse crude pottery. This type of pottery has walls of uneven thickness. There is a great deal of crackle due to natural impurities in the clay. The surface is not burnished, but an attempt at smoothing has been made by scraping. The shape is reminiscent of globular Bantu pottery.





TEXT-FIG. 7.

1. Everted overlap, well finished and burnished.
2. Gimped lip.
3. Vertical neck, sharply shouldered rounded lip.
4. Vertical neck, everted rounded lip.
5. Square lip, vertical neck, shouldered, globular pot.
6. Square lip, neck shallow and sloping into pot belly.
7. Square lip, neck elongated and curving into body.
8. Square lip, shoulderless neck with appliqué work band.
9. Splayed lip, shoulderless with appliqué work.
10. Rounded lip, internally bevelled.
11. Heavy, crude, large beer-pot type, rounded lip, everted and with internal bevel.
12. Rounded lip, internal bevel, everted.
13. Plain tapered rounded lip.
14. Rounded lip, edge incised or notched.
15. Thin, plain taper lip, vertical, to globular small pot.
16. Thinned taper lip.

Compartmented patterns, Site "X," I to VIII.

First period occupation is represented by figs. 1, 2, 3, and 4, and Plate IV, 1, 3, 4, and 6.

Later portion of occupation is represented by figs. 6 and 7.

Second period occupation is represented by figs. 8 and 9, and Plate IV, 8 and 9.

IV, X, XI, XII belong to this and to later Period I.

Third period, latest, not illustrated, comparable with Cathkin Peak and other Bushman pottery, the only difference being greater size.

IV. Coarse, vertical-sided, plain taper lip, of texture and general appearance of Bushman work.

The fragments of Type I are widely scattered, but are not found in the later middens. The body has no admixture of quartz or other substance, which would show careful working of the clay. Late examples of this class imitate the earlier types, but show carelessness in the preparation of clay and in finish of the surface. There are signs of degeneracy in Type I, which suggests that this type of pottery existed for some time.

Type II presents many features so distinct from the preceding that the fact that they are found in later middens, situated over earlier sites, is additional evidence towards my belief that the close of the early occupation was by people of similar blood but of other tribal descent, and probably of a less direct migration from the north. Among these intermediate type potsherds is much that suggests contact with the Bush folk, and here lies the origin of certain of the strange developments of the ceramic art among the Bush folk of the Stormberg and Tarka areas (33), *e.g.* the heavy body with deeply incised patterns, the oval finger-nail impression, which here is a true finger-nail method of working. Here, too, is the explanation of the origin of the pottery claimed as Smithfield by Lowe and Goodwin. Such a pot as that illustrated by these writers was found with a skeleton of the mixed Bush-Bantu type representing the builders of these stone dwellings. The bodies of these pots are similar, as well as the peculiar rolled lip, the development of which is shown in the sherds from these Heilbron mounds, from the square well-trimmed to the overlapping burr, with all the resemblance of a rolled lip.

It is questionable whether the potter's art in South Africa developed *de novo*. Each successive development undoubtedly was due to impact with higher culture migrating from the north. The whole of this subject will be discussed in a separate paper; but there are certain affinities between these southern finds with certain more northerly ones that must be considered here. The colour-burnished pottery with incised geometric decorations has been found at Willowglen, Krugerskraal, Site "X," not seen by the writer, and concerning which a strange secrecy is maintained, and also at Koffiefontein and Tafelkop (fig. 7). Similar pottery has been found at Haenertsburg, near Pietersburg (Witwatersrand Anat. Museum), and also near old workings at Rustenburg (24). The characters of all this pottery are comparable with Khami and Dhlo-Dhlo material attributed by Miss Caton-Thompson to the Ba Roswi (18, p. 177), which she places at some date anterior to 1700. In both areas the makers of this pottery were also workers of metals. This association has been stressed by Dr. Wagner.

Koffiefontein has also produced two sherds of the tall-necked black-

burnished type of Dhlo-Dhlo pot illustrated by Caton-Thompson and attributed by her to about or before the date A.D. 1700. Further sherds of the sloping-neck type of jar, with square lip ornamented with incisions made at right angles to the circumference so common on the Heilbron sites, have been found in a Bantu grave at Lydenburg (Witwatersrand Medical School—A 42). This type was found also at Tafelkop by Professor and Mrs. Hoernlé, and at Vechtkop.

Other comparisons may be made between sherds from this area and those from Rhodesian sites. The colour-burnished pottery with rectangular patterns may be compared with those of Dhlo-Dhlo (17, pl. xxxiii); combinations of bands and triangles may be compared with similar combinations from Khami (*idem*, pl. xxv). The Heilbron appliqué work is reminiscent of the band work on Zimbabwe pottery (17, pl. xxxv, 4.6.7) that occurs in Bechuanaland sites. The herring-bone pattern, formed by two lines of oval stick impressions, is comparable with similarly patterned sherds from Umtali (17, pl. xvi).

Of the products of clay working, the tuyères and the animal models have been described. Concerning the latter, the urban Bantu have even to this day considerable gifts in this direction. The Ba Ila children of Northern Rhodesia still play with spans of clay oxen. Bent (35, p. 175) describes a clay sow in a midden outside the large circular building in the plain at Zimbabwe. Three clay animals were found in the same area by Hall and are illustrated by him (19, plates 3). Laing and du Plessis (31) described a pre-Moselekatse burial at Roodekraal, Transvaal, associated with which they found a clay model of a Wildebeeste bull which is now in the Witwatersrand Anatomical Museum. The skeletal characteristics in this case were comparable with those of certain of the Heilbron finds, *i.e.* a blending of Bantu and Bush characteristics. The pottery object found on Site B, unfortunately incomplete, is certainly a phallus, and is comparable with those illustrated by Caton-Thompson (18, pl. xxv) from Zimbabwe and Chiwona.

(e) *Stone and Glass Artefacts.*—The presence of well-worked implements in bottle glass in the small middens of Willowglen has already been mentioned. These are illustrated in Plate III, 6.

The glass used for the artefacts is a modern type of bottle, black, with moulded neck, probably of the early nineteenth century. One of these flakes shows convergent flaking. Two other fragments show secondary working, one of which is a doubtful point. No implement-bearing sites have been found as yet in the immediate vicinity of these ruins.

Goodwin (31) states that the use of modern glass for implements has given rise to much controversy, and though many so-called glass implements are to be seen in various museums, it would appear as though very

few of them are acceptable. Goodwin possesses only two, one of which he considers doubtful.

The first glass fragments found were rejected, but the subsequent discovery of definite blades, and a bottle base which had undoubtedly been used as a core, forced me to recognise the presence of implements worked in glass. These glass implements were not found in association with pottery of any of the types found in the middens.

A duckbill scraper of translucent stone, 32 mm. long and 19 mm. broad, was found on a midden of the higher culture at Krugerskraal. At Willowglen, a bead borer of the type of Goodwin and Lowe was found beneath a midden belonging to the second period of occupation. These associations and the wide spaces intervening between the stone-hut settlements suggest the intrusion of a higher culture into an area occupied by a lower culture, without the latter's complete disappearance or absorption, and with its very definite survival after the disappearance of the former.

Over the whole Free State area are found carefully worked and polished conical stones. I have not seen such stones in other parts of the country. It is not known to what culture they belong, but I think that they have a phallic significance and are more likely to be related to the builders than to the Smithfield people. They are comparable with those illustrated by Caton-Thompson (18, pl. xix, 2, and p. 48).

Dart (42) has discussed these conical stones. He concluded that they are phallic in character and connected them with the stone hut-builders.

The disc-shaped upper milling-stone with both faces worn is characteristic of the Heilbron sites. It is found also in the Steynsdorp valley (24).

Only three portions of worked soap-stone were found, two being portions of the incised pipe found in the courtyard of Site B, Krugerskraal, and the third being a portion of a plain thick-walled soap-stone pipe, tubular in form, and found in trench 3, Krugerskraal. The internal diameter of each bowl is about 12 mm. These pipes are bevelled at the bowl and from within outwards, and they appear to have been made by cutting and scraping in the direction of the long axis of the pipe. Soap-stone pipes have been manufactured by Bushmen even in recent times. These are usually very different from the Krugerskraal specimens. They are not bevelled at the bowl end, but appear to have been bored with a rotary motion. Their walls are thinner than those of Krugerskraal specimens, and are polished but are not otherwise ornamented.

(f) *Beads.*—Both imported and native beads were found at Heilbron.

Imported Beads.—With the exception of one dubious find at Willowglen, imported glass beads have been found only in the middens of site Willowglen B. Although these beads were found in association with iron objects

of recent European manufacture, it does not necessarily follow that all are of the same age. The following is a list of the beads found:—

(*a*) Eighteen blue glass beads, 9 mm. in diameter and 6 mm. in length, and nineteen fragments of similar beads all wire wound, some less efficiently reheated than others.
(*b*) A fragment of an opaque blue glass bead of large size.
(*c*) Twelve small blue beads, 4×2 mm., showing marked regions of wear.
(*d*) Thirty-four smaller blue beads.
(*e*) One small deep blue.
(*f*) One white.
(*g*) Three white, opaque, very much worn (Beck's type, 8*a*, in 18).
(*h*) Four very small green glass beads, 2×1 mm., and one small fragment (Beck's type, Zimbabwe, 5*a*).
(*i*) Four tiny, of blue glass.
(*j*) One tiny mauve bead.
(*k*) Cane beads. One small grey-blue, and the following others: Some red on white base, three 5×3 mm.; some opaque red on black, five 3×2 mm. Thus there are seventeen varieties of beads of ten colours and combinations of colours.

The blue glass wire-wound beads found on the surface are worn by natives from South-West Africa. A larger type of the opaque red over black cane beads in my possession came from a considerable depth beneath the surface at Clanwilliam, but they also occur in Rhodesia. I have not seen such a selection of beads from the north or east, though (*g*) and (*h*) are later Zimbabwe-type beads. They suggest strongly to me that the route of their travel to Willowglen was from the north and west, *i.e.* along the river's tributary to the Orange.

That beads were found only on this site show that during the period of occupation of the stone-built settlements there was no contact with the European settlements in the south. These beads must have been deposited at a late period, otherwise beads would be found throughout, even if only in small numbers.

The beads can be explained only as the relics of wandering Bushmen who had come into contact with the bead-wearing Korannas in the Orange River area to the west. This would explain also the worked bottle glass and the late date of deposition. I have seen similar small ash middens outside Bushmen werfs (courtyards), adjoining circular stone scherms (outside walls) that had protected the huts, in Little Namaqualand. I believe that these two small Willowglen middens are wholly due to wandering Bushmen and have no connection with the ruins other than propinquity.

Native Beads.—The native-made beads recovered are of two types, viz. cylindrical beads of ivory, and disc-shaped beads of ostrich eggshell. Two specimens of the former type were recovered from trench 2 at Krugerskraal; similar beads are said to have been found at Willowglen but subsequently lost.

A cylindrical ivory bead was found by the writer superficially in a shelter in the Rechtersveld, and another in a shelter on the Keiskamma River deficient in Stone Age culture, denoting a very widespread use of this type of African bead. Those found at Krugerskraal are 1·1 and 0·85 cm. long, and 1 to 1·1 cm. broad. They are cylindrical, and their walls are only 2 mm. thick.

Ostrich eggshell beads were found in the middens both at Krugerskraal and at Vechtkop (Plate III, 1+5 and 2+4). At the former site individual beads were also found accompanying infant skeletons in three pots. These beads are a well-known element of the late Stone Age (Bushman) culture, and are also commonly made by Bantu peoples. Similar beads have been found, however, on the later Rhodesian sites both by MacIver and by Miss Caton-Thompson. They also occurred in one of the Riet River graves.

7. Discussion of Cultures.

(a) *Comparison of Rhodesian and Heilbron Architecture.*—In the foregoing analysis of the culture of the Heilbron settlements frequent comparisons have been drawn between the culture of the earliest Heilbron period (Willowglen I and Krugerskraal I) and that of the Rhodesian ruins. The resemblances are such as to suggest strongly that the source of the Free State stone-building culture is to be found in Rhodesia. This suggestion is supported by a comparison of the stone constructions in these two areas.

The Makalanga huts within the enclosure of the elliptical Temple at Zimbabwe have stone foundations (34, p. 103). Bent (35, p. 118) found outside the walls of "temples or fortresses" circular foundations built of granite blocks, 6 to 15 feet in diameter and built in groups at considerable intervals apart. "Some of these circular foundations have a double circle as if for a step. The probability is that they formed the foundations of stone huts like those found at the Marico district of the Transvaal." No traces of these were found within the walls, but all were situated within a radius of 200 yards. Undoubtedly Bent saw double foundations such as occur in the early stages of the Heilbron architecture. Here is a distinct link in the building method with Rhodesia. The choice of the sites was similar, heights, spurs, and knolls (*cf.* 18, p. 23, Maund ruins). The hut entrances are built upon the same plan as the doors to the pit dwellings at Inyanga

(17, pl. v), with stone lintels and thresholds. Miss Caton-Thompson is convinced that the disconnected stone walls of the Maund ruins originally filled the gaps between huts built of wattle and daub which have since disappeared. Remove the huts from the Heilbron sites and somewhat similar sections of walls would be left. Bonding was unnecessary in the former, and is absent in the latter. In both places the buildings are erected of the material lying at hand (and have caused a distinct clearance of the area of loose stones), and in consequence there are local variations in appearance and finish, but the technique is essentially the same. And at Heilbron the earlier sites have the more massive foundations. The corbelling, which is such a feature of the smaller type of hut in the Heilbron area, is, states Miss Caton-Thompson, unknown at Zimbabwe (18, p. 103), but Randall MacIver shows corbelling in the stone-work of an underground chamber at Nanatali (pl. xx, 11). Further, beehive huts, stone-roofed, of better construction than the Vechtkop type, are reported to exist in the Inyanga Valley north of Umtali (Week-end Advertiser, Saturday, 12th September 1931, by M. M. P.). This, however, is not reported in the detailed survey of this district by Mason (46). Nor could the writer obtain any information concerning them during a visit to Rhodesia in 1933.

Caton-Thompson suggests that two lines of communication traverse the wilderness and connect Zimbabwe with the outer world, one south-east along the course of Mtilekwi *via* the Lundi Valley, along the Sabi Valley to the sea to the south of Sofala; the other running south-west, leading to the ancient workings of the copper-bearing regions of Messina "whose traffic with Zimbabwe may be indicated by the scattered ruins along the line and terminus. Whether the implication of direct traffic is correct or not, concerning the cultural connection there can be no doubt. Wagner has shown that metal-working has flourished from Messina to Aasvogelkop, a distance of 300 miles. I have indicated the similarity in certain pottery finds. Ruins exist in numbers along the line between, but have not as yet (1931) been explored.

The combination of facts is such that it points definitely to the essential similarity in origin of all these stone-building sub-cultures, and there is no reason to suppose that this first migration took place in any other direction from Rhodesia than the direct southerly one.

(b) *Evolution of the Heilbron Culture.*—The indications then are that the stone-building culture of the Transvaal and the Free State is of the same origin as that of Zimbabwe. Certain features point to the southward migration having been a slow one, the stone-roofed huts being more fully developed in the south. So far it is not possible to say whether or not the settlements of the earlier occupation at Heilbron possessed beehive outliers, but these during the contracted later (2nd) occupation certainly ousted

the thatched hut and stone-wall enclosure. It is not therefore possible at present to argue that the corbelled stone roof was freshly introduced by the later migrants, although the gap between the large thatched hut court-yard type of settlement and the small stone-roofed hut individual or cluster is noticeable.

It may be concluded that development was from the plain-walled enclosure towards the stone-roofed corbelled beehive hut. The beehive technique was the method of building in greater favour with the latter people of the Heilbron Sites D and E, and was situated on the slopes of hills more after the manner of the modern Bantu kraal.

In respect of all other aspects of material culture there has been shown to have been marked change, generally in the direction of degeneration, from the earliest to the latest settlements. Thus in the ceramic sphere the vertical-sided pot replaces the globular-necked type, and coarse ware, undecorated or merely finger-moulded, supersedes the early colour-burnished and patterned pottery. The Bantu household set of pots—large beer, medium store pots, medium cooking pots, and small drinking bowls —are replaced by cruder and intermediate sizes.

Iron-smelting deteriorates or even disappears, and at the same time the ogee blade probably replaces the older flat type. Adult burial in middens appears only in the later phases of the settlement, but there is a falling off in the number of infant burials, pointing apparently to a change in ritual, and therefore most probably to a shift of population. The cist-grave is only found in the earlier phase.

The effect of these changes in material culture is to give a diminishing Bantu, and increasing Bush-Hottentot, facies. It is therefore significant that while the earliest discovered remains are relatively pure Bantu, the latter are either Bantu-Bush hybrids or even predominantly Bush.

(c) *Middens as an Index of Antiquity.*—Lowe has estimated the rate of accumulation of the midden deposits at Vechtkop as ½ cubic foot per diem, or about 180–200 cubic feet per annum. He estimates the volume of the certain Vechtkop middens at 6000 cubic feet, giving a duration to the settlement of thirty to thirty-five years.

If Lowe's estimate of the rate of accumulation is valid for the later sites, to which, as we have seen, Vechtkop (as described by him) belongs, it is certain to be inaccurate for the earlier middens at Krugerskraal and elsewhere, in which the material has been consolidated to a much greater extent. However, even when Lowe's calculations are applied only to the later deposits at these settlements, the results are sufficiently impressive.

Two middens at Jamaica indicate a life for that settlement of twenty-five years, a late one at Willowglen represents some forty years of accumulation. It is by no means certain, however, that the whole history of

Willowglen II is to be compressed within that space; in fact, the evidence points to that period having been much longer. At Krugerskraal proof of a longer duration is obtained. The gigantic midden A represents, on this basis of calculation, the accumulation of a century or more. Another huge midden, that near Site H, also indicates duration of a hundred to a hundred and fifty years. These deposits are at most only partially contemporaneous with those of Vechtkop and Jamaica. The beginnings of the occupation of Krugerskraal represented by these middens must therefore be placed very much farther back. It is, however, probable that the whole of this occupation (Krugerskraal II) antedates the foundation of Vechtkop and Jamaica (contemporary with Krugerskraal III).

But these middens at Krugerskraal both partly overwhelm settlements (G 1 and H 1) of the early type; *i.e.* Krugerskraal I. In other words, an occupation of Krugerskraal *terminated* a full century, and perhaps considerably more, before the final destruction of Vechtkop. How long this occupation lasted there is no means of determining. The duration of the settlement cannot well have been less than a generation. It was probably much longer; if Site B (Krugerskraal I,*b*) as well as Site C (Krugerskraal I, *a*) both preceded the accumulation of the great midden heaps, at least another century must be added to the age of these structures. It would be extremely conservative to place the initiation of the Krugerskraal I stone-building activities at A.D. 1670–1700.

Around some sites, as at D, there are middens totalling thousands of cubic yards; at others, as at C, no vestige remains. Some of the pot burials, found a distance below the surface of the middens, show damage to rim and mouth that could only be achieved by gradual consolidation of the midden leaving rims exposed to damage, for the missing portions were not found in the vicinity, as they would have been had the breakage been due to foot pressure in soft ash. This suggests broken continuity in the use of middens as depositing sites, and still further extends the period during which they were in use and gives probability to an earlier date for the Krugerskraal stone-building activities.

8. History.

(a) *Local Traditional History.*—Native statements relating to this site are singularly conflicting. Lowe met with an old Leghoya who asserted that his great-grandfather had lived in one of the stone hut settlements adjacent to Vechtkop. While Lowe interprets this evidence as confirming his view that the settlements (*i.e.* those of the third period) were founded by the Leghoya *circa* 1787, it obviously offers no explanation as to the character of the earlier inhabitants.

The natives (Bush type) living in the neighbourhood of Krugerskraal have a distinct tradition concerning these ruined stads. One aged man, believed to be more than a century old, said that the inhabitants of these stads were lighter in colour than Kaffirs and wore their hair long (? braided), and had Bushman slaves, who lived outside the kraal. This very interesting version may well be the basis of the local European story (which Lowe rejects) that the builders of the stone huts were Bushmen. The picture of the inhabitants drawn by this informant is far more like the Hottentot than like any Bantu group. It needs cautious interpretation, however, for while there is a possibility of a Bush-Hottentot occupation having preceded the Leghoya at Krugerskraal, there is definite evidence that such an occupation followed the Leghoya period at Willowglen.

Tradition, however attractive, must not be relied on unless the qualifications of the informant are beyond reproach. Thus a Zulu, one who was able to give a complete and accurate account of the history of Natal and Zululand, stated that the Vechtkop remains were the work of Moselekatse. This case is further interesting for the bearing it has upon the commonly received tradition that Moselekatse was the founder of the Aasvogelkop settlements, which have many similarities with the earlier type of stad. In South Africa so widespread are the Moselekatse stories, and so much is shouldered upon him, that all such traditions are best discounted.

(b) *General History.*—Concerning the early history of the Bantu in the Orange Free State there is a great variety of opinions. Lowe, on the authority of his Leghoya informant, attributed Vechtkop (as described by him, *i.e.* Vechtkop II) to that people, and on the basis of his estimate of the rate of accumulation of midden deposits, dated the foundation of that site to *circa* 1787. Yet on his map he dates the migration of the Leghoya ± 1700. For this he indicates no authority.

Stow (34) and Theal (38) agree that the Leghoya or Bataung (these names are regarded as synonymous by both these authors) were the first Bechuana people to migrate to the south of the Vaal River. To this movement Stow assigns no date. Theal declares that "the eighteenth century was far advanced before the Bechuana crossed the Vaal River. The Bataung, who had been compelled to flee from the Barolong, set their faces south-eastward from their former home on the Setlagoti, crossed the Hart and the Vaal, and took up their residence on the upper course of the Vet River" (p. 189); and again: "about the middle of the eighteenth century the Barolong crossed the Molopo and dispersed the Leghoyas or Bataung, who, however, were able to retreat to the east with their cattle."

Theal's dating of these events places the arrival of the Bataung very close to Lowe's date for the foundation of Vechtkop II and of the apparently

contemporaneous sites. It has been shown, however, that at Krugerskraal, and probably also at Willowglen, Period II extends back for perhaps a century before the date assigned by Theal to this migration.

A very different account of the advance of the Bantu tribes into the Orange Free State is given by Ellenberger (44). In the first place, this author differentiates the Leghoya from the Bataung. The former he confines to the territory west of the Valsch River. He admits their claim to have been the first immigrants into the territory south of the Vaal, but dates this movement early in the seventeenth century. The Bataung he describes as occupying the valley of the Rhenoster River (*i.e.* the Heilbron area), and later expanding towards the south-west to the Valsch and Vet Rivers. The arrival of the Bataung in the Heilbron district is dated *circa* 1650. Some time between 1800 and 1820 the Bataung overthrew and absorbed the Leghoya, and this probably explains the manner in which Stow and Theal treat the two groups as one.

Ellenberger's dating of these events is based on the genealogies of the tribal chiefs, reckoning a generation as approximately thirty years. It is possible to argue that the estimate is excessive, that a chief's reign would tend to be less than an average generation. Correction on these lines, on the basis of four reigns to a century, would reduce the dating by about thirty years, bringing the arrival of the Bataung on the Rhenoster River to A.D. 1675–1700. This date is the same as that quoted without evidence by Lowe, but, further, it is the approximate date which our deductions from the midden deposits have led us to assign to the foundation of Krugerskraal II.

If Ellenberger is to be trusted, it would seem that we can identify his Bataung with the founders and inhabitants of Krugerskraal II and other second-period settlements. This view is supported by several other considerations. One of the outstanding differences between Vechtkop and the sites nearer Heilbron is that at Heilbron there are settlements (third period) built over earlier middens, whereas at Vechtkop there is no trace of midden building. Ellenberger's account of the gradual expansion of the Bataung to the south and west agrees well with the explanation which we had independently suggested for this, namely, that Vechtkop represents a later southward expansion of the people of Krugerskraal II.

In addition to this it is to be noted that we have seen reason to believe that the inhabitants of the settlements of Periods II and III did not smelt metals. Professor Maingard in a forthcoming paper presents evidence that the whole of the group of Bechuana tribes to which the Bataung belonged did not practise smelting.

One objection to the identification of the people of these settlements with the historic Bataung, is that Ellenberger not merely does not attribute

stone dwellings to this tribe, but definitely asserts that at the time of their flight from this area their dwellings were of wood and thatch. It must be observed, however, that on the subject of stone huts Ellenberger is an unreliable witness. He repeats on the authority of Stow the tradition relating to the building activities of the Leghoya, while at the same time carefully excluding them from the territory within which stone buildings are found. Beyond this his sole allusion to this topic is a tradition regarding the BaRamokhele, which borders on the fantastic.

Both Stow and Ellenberger emphasise the friendly relations which the Leghoya-Bataung entered into with the Bushmen. Stow says that the Bushmen of the "Gij Gariep" (Vaal River) had their headquarters near Pneil. They had advanced to a comfortable stage of existence, especially along the Vet River, "where the friendly intercourse which had sprung up between the Leghoya, an emigrant tribe of the Bachoana, who had settled among them, had been beneficial in raising them in the scale of comfort and civilisation far beyond that found among any of the western tribes. They had become semi-pastoral, possessing comparatively many cattle." It must be remembered that the Bushmen of this area were themselves builders in stone (Stow, 34), and certain ruins, *e.g.* at Halfway House near Pneil (the headquarters of the Vaal River Bushmen), are attributed to them.

Ellenberger remarks that the Bushmen were employed by the Bataung as herdsmen. They lived at a distance from the villages. Relations between the two races must have been amicable, since it is said that the great Bataung chief Moletsane was entrusted to the Bushmen at one of these outlying cattle-posts to be reared, and that he gained his name, or rather nickname, from the girdle of ostrich eggshell beads made for him by the Bushmen.

It is evident that under such conditions as these the line of distinction between Bantu influenced by Bushmen and Bushmen influenced by Bantu must have tended to become very obscure. This readily explains the peculiar mixed aspect of the culture of Krugerskraal II and III, especially the latter.

It has been pointed out that an increasing number of the cultural manifestations of Periods II–III are "Bush" in the broad sense, *i.e.* they are the work of men of the Bush physical type as defined in the appended report on the skeletal remains from these sites. Some of these features may well prove, however, to be in the cultural sense not Bushmen, but Hottentot. That is to say, they are derivatives not from hunting but from the pastoral culture.

The Hottentot kraal, as described by explorers from the Cape in the year 1661 (22), was a circle of huts, outside which other huts (outliers)

were occupied by messengers and Hottentots who possessed no cattle. No mention is made of circular fences, but similarities with several of the types of stad described in section 3 of this paper at once spring to mind. The stads which show these resemblances are all apparently referable to the later period. There was, on ceramic evidence, undoubtedly a line of contact along the Riet River between Hottentots and the earlier inhabitants of that area. The Riet River burials and the Krugerskraal burial all point to influences from the west.

The most probable explanation of these observations is that the Leghoya and Bataung, either during their sojourn in the west or in the course of their eastward movement, came into intimate association with the Hottentots and absorbed from them certain elements of culture. If the Bataung were already infiltrated with Bushman blood before their arrival on the Rhenoster River, the unusually friendly relations between them and the Bushmen in that area appear more easy of explanation. That there was a great mingling both of physical types and of cultures in this area at this time cannot be doubted from the evidence before us. Ultimately there can hardly have been any criterion (other than linguistic) to permit of the peoples of this area being identified as Bushmen, Hottentots, or Bantu.

We have seen that the second and third periods of occupation are to be attributed to a people and culture of Bantu origin possibly influenced at the onset by Hottentots, but in any case becoming progressively Bushmanised with the lapse of time. This people are almost certainly to be identified with the Bataung of history. The people responsible for the first occupation period are still unaccounted for. We have seen reason to regard them as southward Bantu migrants from Rhodesia, either Baroswi or Makalanga. There is such a hiatus in every aspect of culture between the first and second building periods, that one cannot do otherwise than assume either that the people of the first period have died out before the arrival of those of the second period (supposed Bataung), or that they were either annihilated or expelled by the latter. At all events their impress on the later culture of this area is negligible.

The catastrophe which terminated the first period of occupation must therefore have occurred certainly before 1700, and probably not later than A.D. 1650. The commencement of this period we have seen reason to date between 1550 and 1650, but more probably nearer to the earlier date. This conclusion is in agreement with the comparisons drawn between finds from these early settlements and those from Rhodesian sites dated to before A.D. 1700. It agrees also with the fact (Theal, 38) that after 1500 the Makalanga kingdom was in a state of disruption, and that from 1550 to 1650 it was the prey of warlike hordes from the north. That is to say, the conditions in Rhodesia at this time were such as to favour a southward

migration. Later, if we are to accept Caton-Thompson's dating for Dhlo-Dhlo, there was a renaissance in Rhodesia and probably a cessation of the movement to the south.

9. Description of Human Remains.

In addition to the four interments already described, stray fragments representing a number of individuals have been obtained from the Krugerskraal and Willowglen sites. There are also fourteen foetal and infantile skeletons found buried in pots, but only one of these permits of a definite determination of race. For the diagnosis of the physical character of the inhabitants of these sites we have in all remains of nine individuals. A summary of these is given in the following table:—

Site.	No.	Age.	Condition.	Circumstances of find.
Vechtkop .	V. I	Adult	Fragmentary skeleton	Cist - grave beneath midden.
Willowglen .	W. I	,,	Mandible	Stray in midden.
,, .	W. II	Juvenile	Maxilla	,, ,,
,, .	W. III	Adult	Skeletal fragment	Stray in excavation of midden.
Krugerskraal	K. II	,,	,, ,,	? Pot burial, Site A.
,,	K. III	Infant	,, ,,	? Pot burial, Site D.
,,	K. IV	Juvenile	,, ,,	? Grave, trench 2, Site D.
,,	K. V	,,	Well-preserved skeleton	Grave, trench 3, Site D.
,,	K. (W.)	,,	Fragment of skull	Stray.

Remains from Vechtkop.

V. I (*Adult*).—The skeleton from the Vechtkop cist-grave is in a very imperfect condition, being represented by fragments of vertebrae and of pelvic and limb bones in a very fragile state. The best-preserved portions are the shafts of the femora and tibiae. These permit of direct comparison with the remains from Vechtkop described by Dart in the appendix to Lowe's report (1927).

The shafts of the femora of V. I are distinctly larger than the corresponding portions of the earlier Vechtkop skeleton, indicating a greater stature. The platymeric index of V. I is 77·5. This agrees closely with that of the earlier specimen, and like it is much closer to the Bushman than

to the Bantu average. In the pilastric index a great difference between the two individuals is apparent. The earlier find gave the high pilastric index of 115, approximating to the Bushman average. In V. I this index is no more than 100, which is much closer to the average for the Bantu.

The tibia of V. I is slender and decidedly convex anteriorly. The platycnemic index is 80, which is considerably higher than that of the earlier skeleton, and again nearer to the Bantu than to the Bushman average. The other bones are in a fragmentary state and reveal no racial peculiarities.

The earlier Vechtkop find was regarded by Dart as a Bantu-Bush hybrid type. The taller stature of V. I and the platycnemic and pilastric indices suggest that this individual is of a purer Bantu stock. That it was found wholly beneath midden level is of importance and suggestive.

Remains from Willowglen.

W. I (*Adult*).—This individual is represented only by a mandible. This is of large size and massive appearance. Comparing it with the descriptions of the Bush and Bantu mandibles given by Miss Salmons (1925), it appears to present a mixture of Bantu and Bush features. The ascending ramus is high and narrow, as in the Bantu, but resembles that of the Bushman in being set at right angles to the body of the mandible. The angle of the mandible is everted, a Bushman feature. The upper and lower margins of the body of the mandible are parallel as in the Bushman, but the body is not unduly thick, in this resembling the Bantu. There is a prominent chin, a Bantu feature, but the degree of alveolar prognathism is less than in typical Bantu mandibles. Large genial spines are present on the lingual surface. The teeth are very deeply worn.

The mandible thus presents a mingling of Bush and Bantu features, but the latter are more pronounced. The individual is therefore to be regarded as a Bantu with some Bushman admixture.

W. II (*Juvenile*).—The specimen is the left maxilla of a child in which the lateral permanent incisor is unerupted, *i.e.* of about seven to eight years of age. In absolute size it is similar to the maxilla of a Bushman child of this age. It shows, however, an increase in the vertical diameter of the face, a greater prominence of the nasal region, and an increased total prognathism. In these respects it approximates to the conformation of the Bantu maxilla, but the maxilla of a Bantu child of this age is considerably larger in absolute dimensions. These observations suggest that we have here again an individual of mixed Bush and Bantu origin.

W. III (*Adult*).—Under this designation are included certain skeletal fragments found in the excavation at Willowglen. The finds were dis-

sociated from one another, but show sufficient agreement in preservation and morphological features to make it probable that they are remains of a single individual. They comprise the atlas, the proximal portion of the left humerus, and the right ulna, lacking its distal end, and much crushed and eroded.

The atlas, both in size and in conformation, is much more similar to that of the Bushman than to that of the Bantu. The limb bones are larger than those of most Bushmen, but are smaller than those of the average Bantu. They reveal, however, no structural peculiarities which would serve to distinguish one of these races from the other. The determinable characters of the fragments warrant us in referring them to the same Bantu-Bushman hybrid type as is represented by the other skeletal remains from Willowglen.

Remains from Krugerskraal.

K. II (*Adult*).—This individual was obtained from the supposed adult pot burial on Site A. It is very fragmentary, being represented by the symphyseal portion of the mandible, a number of teeth, and remains of vertebrae, ribs, and pelvic and limb bones.

The fragment of the mandible is closely similar to the corresponding portion of the mandible of W. I. It is slightly smaller, with a somewhat greater degree of alveolar prognathism, and only very slight genial tubercles. The teeth are not worn low, but are grossly affected by periodontitis.

The atlas, which is partially preserved, is of Bushman type, but the thoracic vertebrae rather resemble those of the Bantu. This is true also of some small bones of the hand. A portion of the right ilium is present, and indicates the remains to be those of a female. The remaining fragments reveal no racial characters.

These remains suggest an individual of the same type as W. I, but with even more pronounced Bantu features, thus tending towards the type of V. I.

K. III (*Infant*).—These remains are those of a full-term infant from a pot burial on Site D, Krugerskraal. A determination of the race of this individual is possible owing to the excellent preservation of the skeleton of the jaws.

The maxillae clearly reveal the negroid character of the remains, but in the present state of our knowledge it is impossible to determine whether the maxilla is of Bush or Bantu type. More definite evidence of race is provided by the mandible. This has a less receding mental region than that of the Bushman infant (Wells, 1931), and the inferior border of the body of the mandible is uniformly concave, and not sinuous as in the Bushman. The mental fossa is more pronounced than in the Bushman

infant. Both of the latter features of this mandible share with that of a Bantu child aged about six months. The ramus of the mandible is higher and narrower than that of the Bushman, though less narrow than that of the European infant, and the angle of the mandible is not so markedly everted as in the Bushman infant.

From these observations this individual appears to be of Bantu or at least of mixed Bantu-Bush type.

K. IV (Juvenile).—The remains of the juvenile skeleton from trench 2 at Krugerskraal are much broken and very fragile. They represent an individual in which the deciduous canine teeth were in process of eruption, *i.e.* a child of about eighteen months. A determination of the race of the remains can none the less be made with a high degree of accuracy, owing to the preservation of part of the right maxilla and the anterior portion of the mandible with the teeth.

These fragments show no greater differences from those of a Bantu child of twenty-one months than are to be accounted for by the slight discrepancy in age. On the other hand, the jaws of a Bushman child in which the second milk molars are already erupted are proportionately smaller, and the maxilla distinctly less prognathous. The mandible of the Bushman child also has a definite "platysma tubercle" (Wells, 1931), which is absent from the Krugerskraal fragment and from the mandible of the Bantu child. In addition, the milk molars of the Krugerskraal child agree in size and form with those of the Bantu, but are appreciably larger than those of the Bushman child.

The fragmentary remains of the other skeletal parts do not throw any further light on the race of this individual. The evidence of the jaws and teeth is, however, sufficient to identify the remains as of predominantly Bantu character.

K. V (Juvenile).—The skeleton from the grave exposed by trench 3 in mound A at Krugerskraal is by far the best preserved of the individuals from these sites. It is that of a child in which the second permanent molars are commencing to erupt, *i.e.* of about eleven to twelve years (*vide infra*). Unfortunately it reveals evidences of serious constitutional disease which to some degree obscure the racial characters of the skeleton.

The *skull* shows the unusual anomaly of complete synostosis of the sagittal suture. In consequence of this its outline in norma-verticalis is excessively long and narrow, the condition known as *scaphocephaly.* This deformity robs us of the valuable indication of race normally furnished in South African skulls by the cranial form. The parietal bosses are actually well developed, but as a result of the deformity they do not determine the outline of the cranium in a vertical view as they do in a normal skull.

The contour of the skull in norma-lateralis, however, does not reveal

evidence of distortion. In this view the skull presents a general similarity to the Roodekraal skull (Laing and du Plessis, 1926). It is, however, higher vaulted and fuller in the parietal region, thus approximating to the Bantu form, whereas the Roodekraal skull has the contours of a Bush skull.

The glabella and superciliary eminences of K. V are very prominent, considering the immaturity of this individual. There is a large inferior frontal eminence. The mons-tempero-sphinoidale is not very large, but passes backwards into a bold projection at the parieto-squamous sutire, which is a feature of the juvenile Bush skull. The mastoid portion of the temporal bone is inflated, but the actual mastoid process is very small.

The face is long and prognathic. The orbits are oval and very obliquely placed, and have slender margins. The nose is mesorhine and its inferior margin is rounded off. The palate is shallow and very tapering anteriorly —an "adenoid palate." There is a slight torus palatinus. The left lateral incisor is deformed, and the right first molar seriously decayed. The second molars are in process of eruption; the second premolars are already fully erupted.

The ramus of the *mandible* is high and narrow, with a deep sigmoid notch, thus conforming to the Bantu type (Salmons, 1925). The inferior angle is not everted. The body of the mandible, however, is of the Bush type, having its superior and inferior borders parallel, though it is more slender than is usual in the Bushman. There is a well-developed chin and slight alveolar prognathism. A slight genial fossa is present.

In conformity with the shape of the palate the inferior dental arcade is very contracted. Consequently the incisor teeth are crowded. The recently erupted second premolars are also considerably out of alignment. The left first molar is decayed. The second molars are in process of eruption.

The fact that in this skull the second premolars are fully erupted, while the second molars are still in process of eruption, renders it almost certain that this individual is not a pure Bushman. Drennan (1932) has shown that in the Bush race the second molar erupts before the second premolar; in the Bantu, as in the European, the order is reversed.

The bones of the vertebral column are slender, and directly comparable with those of Bushmen. The sacrum is long, narrow end flat, and it is worthy of note that the dorsal arch of the third sacral segment is not united in the mid-line. The bones of the *superior* extremity also are slender. The olecranon fossa of the humerus is not perforated.

The *femur* is slender and not excessively curved. Its platymeric index of 81·8 is intermediate between Bantu and Bushman but nearer to the latter, while the pilastric index is extremely high (135·3–137·5), definitely associating this skeleton with primitive races such as the Bushman. The

tibia is straight, and in its platycnemic index (73·1–80·8) approximates much more nearly to the Bantu than to the Bushman. The other bones reveal no racial peculiarities.

The femur is about 3 cm. longer than that of the Matoppo skeleton described by Drennan (1932) (also an individual of ten to eleven years). The stature of the Heilbron individual must therefore have been several inches more than that of the Matoppo child, and thus nearer to the Bantu than to the Bushman.

In appraising the character of this skeleton it is necessary to take into account those features which are due, firstly, to its immaturity, and secondly, to constitutional disease. Despite the difficulties presented by these two factors we are able to recognise a mingling of positive Bantu and Bushman characters. Some of the Bushman traits are very strongly marked. The evidence of the dentition and of the stature, however, indicate that we cannot regard this individual as a true Bushman, but rather as a Bantu showing strong Bush influences.

K. (*W.*) (*Juvenile*).—This individual is represented by the greater part of a frontal bone, apparently of a child about three years of age. Compared with the frontal bone of a Bush child of similar age the fragment is longer and narrower. The frontal bosses are less prominent, the forehead passing gradually into the vault, which rises higher at the bregma than that of the Bush skull. Allowing for the difference in age, the frontal contour of this fragment is not unlike that of K. V. This individual may therefore be regarded as of predominantly Bantu character.

Summary.

Physically these remains fall into two groups: V. I, K. II, K. III, K. IV, and apparently K. (W.) are of relatively unmixed Bantu character, whereas K. V and the Willowglen fragments agree with the Vechtkop remains described by Dart in being of mixed Bantu-Bush origin.

The fragments found stray cannot be assigned to any definite period within the history of these settlements. Those fragments found in graves or in the course of excavations can be assigned to their relative positions. It thus appears that at Vechtkop V. I is more ancient than the Bush-Bantu remains previously described. The evidence from Krugerskraal is consistent with this, for the deposits in which K. II and K. IV were found are more ancient than the mound A in which K. V was buried. Of the Willowglen individuals only W. III is dated, and this also comes from a late mound.

The available evidence indicates, therefore, that the two groups of remains belong to different periods in the history of the settlement, the purer Bantu group being the older, the Bush-Bantu hybrid group the more recent.

10. Description of Animal Remains.

The bones of animals found in the midden deposits can be divided into two groups. The first and larger group consists of the bones incorporated in the middens at the time of its formation. The second includes those remains which have been introduced into the middens subsequent to their formation.

This latter group may be dismissed in a few words. It comprises the burrowing animals, *Susicata* (meerkat), *Xerus* (ground squirrel), and *Pedetes* (spring-hare), which have chosen the soft midden ash for their dwellings in preference to the hard surrounding soil. The bones of these animals are entire, and sometimes in articulation and even enclosed by mummified skin.

The bones of the former group, which are broken into fragments and sometimes burned, represent the kitchen débris of the ancient inhabitants. They include the remains both of wild and of domesticated animals, showing that the occupants of these sites were pastoralists but also obtained food by the chase.

The wild species identified are:

Hippopotamus amphibius: represented by two teeth from midden A, Krugerskraal.

Equus quagga burchelli: jaw of a young individual and a tooth of an adult, also from midden A, Krugerskraal.

Antidoreas euchore (springbok): remains of this animal are very abundant on all of these sites. The teeth of the springbok are very similar to those of the domestic sheep, but careful comparison has established the fact that all of the Heilbron fragment belong to the wild, not the domesticated, animal.

Damaliscus pygargus (Blesbok): represented by numerous fragments from all these sites.

Connachaetes Taurinus (Wildebeeste): a few fragments from Krugerskraal only.

Hippotragus sp.: a number of teeth of a large antelope, either the Sable or the Roan antelope. It is not possible to determine this species more accurately owing to the lack of material for comparison.

The bones of domesticated animals all belong to oxen. No remains of sheep or goats have been identified; as has been pointed out, all of the sheep-like material has proved to belong to springbok. The bones of oxen, however, are very numerous, representing fully half of the collections. The only deposit from which recognisable bones of oxen were not obtained was mound B at Krugerskraal.

The teeth of the oxen from the Heilbron settlements are appreciably

smaller than those of the modern oxen available for comparison. It is worthy of note that the teeth from mound C at Krugerskraal are not so small as those from the later mound A at the same site and from the Willowglen mounds. The number of specimens is insufficient, however, for a dogmatic assertion that there was a change in the type of animal represented. Only one fragment of a horn-core is available; this came from mound C at Krugerskraal, and indicated a large-horned type of ox.

The significance of these features cannot be fully understood owing to the present lack of knowledge regarding the ancestry of the South African domesticated animals. The scanty facts available on this topic have been summarised by Dart (1933). He points out that two strains are recognisable in the indigenous cattle of South Africa. The one is the humpbacked type with short, much-curved horns, the typical "Kaffir ox," obviously derived from the stock of the Indian Zebu, *Bos indicas*. The other type has large horns with divergent tips. This is represented to-day by the Afrikander and similar large draught oxen. Its affinities are clearly with the large-horned oxen of ancient Egypt, which belong to the type named by Duerst (1908) *Bos taurus macroceros*.

The proportions of the horn-core from Krugerskraal are directly comparable with those of *Bos taurus macroceros*. The teeth also agree with those figured by Duerst as belonging to this type. It appears then that the ox of the Heilbron settlements was of the *macroceros* type, at least in the earlier periods. It has been indicated above that there is a possibility of a subsequent change in the type of ox.

The interpretation of these results must remain in doubt until it is known to what waves of immigration the advent of the two types of ox is to be ascribed. A proper study of the historical data should enable us to ascertain whether the oxen of the Hottentots and of the various Bantu groups were of the *macroceros* or the *indicas* types. Given such information it would be possible to draw more extensive conclusions from such evidence as is furnished by the animal remains from Heilbron.

11. Conclusions.

The observations made on these ancient settlements have proved conclusively that the more important sites (Willowglen, Krugerskraal, and Vechtkop) show two clearly defined occupation periods, separated by a pronounced change in every aspect of material culture. At Krugerskraal at least there is evidence of a third occupation, intervening between the other two, but sharply demarcated at all events from the first.

The first-period inhabitants possessed a culture of relatively high standard. Their huts were of large size, with massive stone foundations

and thatched roofs, and built round a courtyard, not a kraal. Stone-built hut hearths, pavements, and paths reveal the owners' regard for material comfort, as does the careful removal of all refuse to middens at a distance from the stad. Iron and bronze were smelted and worked; the former was smelted on hearth furnaces. Pottery was colour burnished, with geometrical designs. The characteristic pot has a globular body and short vertical neck. Small stone granary platforms were in use.

The early settlements were independent social units, and the absence of fortification indicates the peaceful character of the population. The ancient inhabitants were strict adherents to old standing law and custom. The whole of their material culture points to direct affinity with the north and east Bantu. It appears highly possible, therefore, that this most ancient occupation was the work of Makalanga or Baroswi (Monomotapa) emigrants from Rhodesia. The migration certainly took place before 1700, and probably between 1500 and 1600. It thus falls in between the decline of the Zimbabwe culture and the Dhlo-Dhlo renaissance (on Miss Caton-Thompson's dating), and at the very period at which the Rhodesian peoples were being subjected to pressure from the north and west.

The first period had a long life, as is evidenced by the construction of Site B on top of Site C. The existence of a phase of degeneracy in Type I pottery confirms this. A life of a century (three generations) is the minimum that can be allotted to this occupation, but ultimately some catastrophe overwhelmed the settlers, and after a greater or lesser interval a new population of markedly different cultural standing took their place.

At Krugerskraal these newcomers heaped up, over the hut foundations and paved pathways of the earlier inhabitants, the huge middens whose accumulation has been estimated to have required a full century. These people greatly extended, if they did not initiate, the use of the stone-roofed type of hut. To them is also to be attributed the paved platform of large diameter. They were the makers of the intermediate type of black pottery with its appliqué bands and finger-nail ornamentation. Metal working appears to have declined greatly. The bones found in the middens show that they were a hunting and also a cattle-keeping people. Judging by the Krugerskraal skeletal material they were at least in part of Bush-Hottentot physical type, and practised what are regarded as Hottentot burial customs.

It must therefore be concluded that this second occupation was the work either of Bush-Hottentot people or, more probably, of a Bantu people considerably influenced by the Hottentots. Our picture of these people based on the archaeological evidence agrees so closely with Ellenberger's account of the Bataung, that it appears reasonable to regard them as the builders of the second-period settlement.

To the Bataung we may also ascribe the remains of the third occupation period at Krugerskraal, as well as the Vechtkop structures described by Lowe and corresponding remains at Willowglen and Jamaica. Stone-roofed huts are now almost invariable; not infrequently they are built over the middens of the earlier inhabitants. Stone-paved granary platforms are absent. Evidences of metal working are scanty; possibly this metal was never smelted from the ore but obtained by trade. Pottery is coarse and crude, resembling Bush fabrics (Type IV). Pot burials of infants appear to be scarcer than in the earliest period. Human remains are all of the mixed Bantu-Bush type.

Such sites as Vechtkop, which present a mingling of the characters of the second and third periods, may be attributed to the expansion of the Bataung to the south and west. This expansion continued until the commencement of the Mantatisi and Matabele raids about 1820. The Bushman facies of many aspects of the culture of this period is noteworthy. Apparently the Bantu element in the culture was being swamped by the Bush-Hottentot element; while at the same time the Bush people were absorbing elements of higher culture from the invaders.

Finally, after the expulsion of the Matabele, wandering Bush people squatted on these sites. These people were the wearers of imported European glass beads, and makers of stone and in many cases glass implements.

The line of demarcation between the second and third occupation periods is at times difficult to draw. In fact, they represent but the beginning and end of a cultural evolution. The earliest occupation is sharply distinguished from both of these. It would appear justifiable to describe the latest period, which was that first reported upon by Lowe, as the *Vechtkop Phase*. The earliest period had not been recognised previous to this investigation. As its relics and their implications have been most carefully studied at Krugerskraal, it would appear fitting to name this the *Krugerskraal Phase*.

This investigation of the Heilbron stone-building manifestations, though only a small one, has produced evidence pointing to the essentially similar origin of the stone-building cultures of Rhodesia, and of the existence of remains pointing, first, to a direct and southerly migration of the Bantu; second, to a period during which Bantu became Bantu-Bush; and third, to a contact with Hottentot culture along the tributaries of the Orange River. The impacts of this mixed culture were felt by the Bushmen of the Stormberg-Tarkastad region and are reflected in their pottery. It is still necessary to separate out the types of stad according to age and owner. It has pushed back the clock so far as the early Bantu migrations in this area are concerned, and gives evidence of a more ancient (sixteenth century)

migration and massacre preceding that of Moselekatse. These indications, if followed up, will throw considerable light on the movements and the extent of the movements of the early Bantu migrations, and their cultural impressions upon the surrounding people. The importance of these sites cannot be too strongly insisted upon, but it is obvious that the investigation of the myriads that remain will be beyond the means of any single individual.

12. Acknowledgments.

Certain acknowledgments were made in the opening chapter, with special reference to field work. Since then much assistance has been received from others in the preparation of this paper, which also must receive due acknowledgment: Professor Dart for his interest and encouragement and the typing of the earlier drafts; Mr. Wells for assistance in shaping the paper, and for the historical and anatomical sections; Dr. Galloway for final revisions; Dr. Le Helloco of Messina for preparation of the black and white sketches for reproduction; and Miss D. Cumming for the final typing. To all of these I tender my very grateful thanks.

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EXPLANATION OF PLATES.

Plate I.

1. Willowglen Hut. Vertical external wall on right, inner vaulted wall centre.
2. Willowglen Hut, section of. Showing double wall.
3. Vechtkop. Outlier, showing vertical external wall and rubble dome.
4. Krugerskrall. Paved bordered pathway, 4 feet 6 inches broad, 30 feet long. Site B, centre. Site D to left of motor-cars.
5. Cobbled pavement at entrance of left-hand hut, Krugerskraal, Site B.
6. Krugerskraal. Massive foundation of huts partly overwhelmed by middens, Site D.

Plate II.

1. Willowglen. Paved platform surrounded by stones. Modern square erection in background.
2. Willowglen. Large paved platform over midden.
3. Willowglen Hut. Shows single layer of stone for door side. Large stone to right is the displaced lintel.
4. Willowglen. Later square and circular erections (see also 1).
5. Krugerskraal. Double ring foundation of hut, floor clay, Site D.
6. Krugerskraal. Site B, circular hut hearth.

Plate III.

1. Krugerskraal. Strigil, 2 bone awls, surface, Willowglen. Vechtkop: bone awl, surface. O.E.S. beads and mining gad.
2. Krugerskraal. O.E.S. beads. Clay Wildebeeste cow. Two *Cypraea annularis* or *moneta*, ground to form amulets. Fragment iron blade. Fragment baked clay (phallus).
3. Bevelled hoe-head, Willowglen.
4. Two crucibles, Vechtkop (Witwatersrand Ethn. Museum).
5. Centre: large leaf-shaped bevelled hoe. Sides: 2 axe-heads. Above: fragment of third axe, 2 razors, Krugerskraal.
6. Glass flakes, Willowglen.

Plate IV.

1. Red burnished pottery, Koffiefontein (Witwatersrand Ethn. Museum).
2. Red burnished pottery, geometric design, in square impressions, Tafelkop.
3. Heilbron, Site "X." Colour (2) burnished pottery, geometric designs.
4. Krugerskraal. Surface roughly incised chevron pattern.
5. Koffiefontein (Witwatersrand) finger-nail pattern.
6. Amphora-shaped base. Krugerskraal, Site B.
7. Two pot burials, *in situ*, Krugerskraal, trench 2.
8. Finger-nail patterns forming herring-bone design and ribs.
9. Appliqué bands. Finger worked into patterns.

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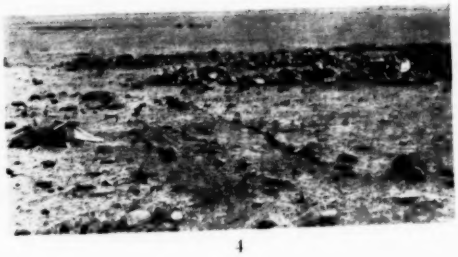

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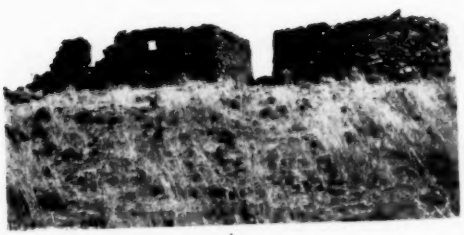

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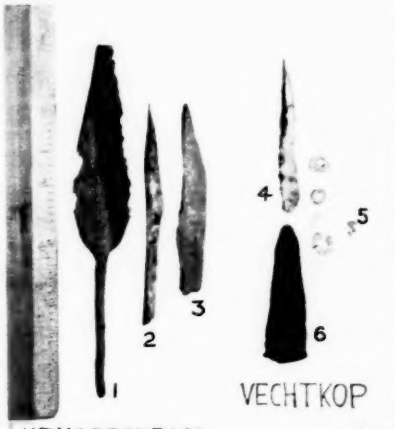

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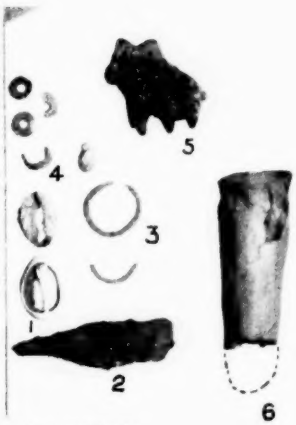

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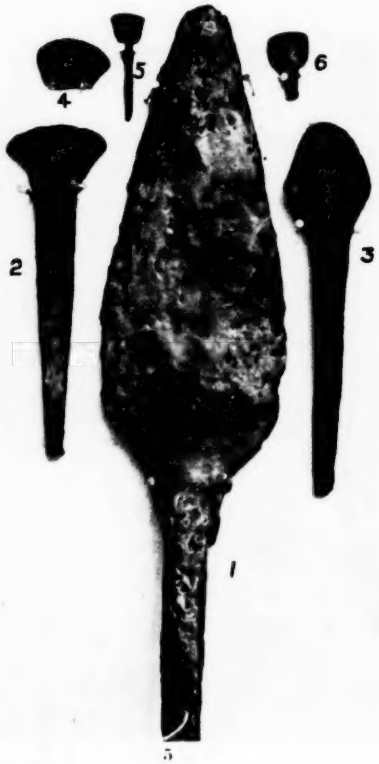

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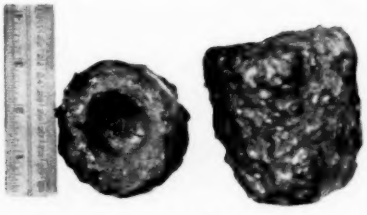

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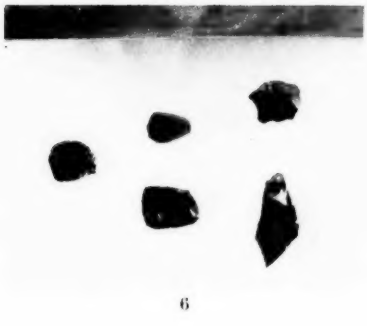

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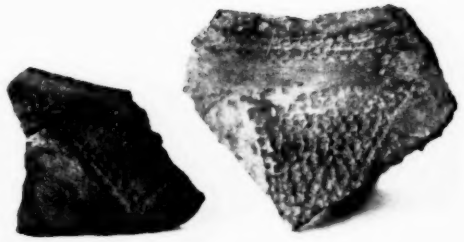

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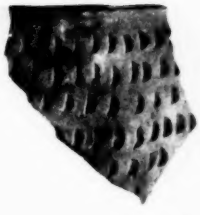

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NEW SOUTH AFRICAN SOLIFUGAE.

By R. F. Lawrence, B.A., Ph.D.,
Assistant in Charge of Arachnida, South African Museum, Cape Town.

(With 11 Text-figures.)

(Read July 8, 1934.)

In the following paper a number of unknown forms of South African Solifugae are described; of the new species half are recorded from the Namaqualand area, which is here regarded as extending from St. Helena Bay northwards to the Orange River and bounded on the east by the 20th meridian. This arid and stony region, with its comparatively low rainfall, contains a larger proportion of Solifugid species than perhaps any other part of South Africa. Roewer, in his recent monograph on the Solifugae, gives the number of species found in the South African region as roughly 150, and of these about 25 per cent. are found in Namaqualand, which has an area only one-twentieth that of the total South African region; even if allowance is made for the possibility that the remaining parts of South Africa are poorly explored regions, an allowance which, for some areas at least, should be unnecessary, there is still a large enough discrepancy to suggest that the Namaqualand subregion is peculiarly rich in this particular order of Arachnids. The fauna is characterised by the comparative absence of Solifugae of large body size as represented by the family Solpugidae, and the presence of numerous species of moderate or small body size comprising the remaining South African families. The number of diurnal forms is few, the great majority of the species being found in their hiding places under stones during the day.

Genus Biton Karsch.

Biton, Roewer, C.Fr., 1933. Bronn's Klass. u. Ord. des Tierreichs, Band V, Abt. 4, Buch 4, Lief. 3, p. 390.

Biton crassidens n. sp.

(Fig. 1.)

1 ♂, Bowiesdorp, Little Namaqualand.

Colour.—Headplate with deep purple infuscation, mandibles with lighter infuscation and only faint indications of a median and lateral stripe;

appendages (both the fourth legs missing) yellow brown except metatarsus and tarsus of palp which are lightly infuscated; dorsal surface of abdomen with 3 rows of dark purplish spots, a similar row at the sides of the under surface, the spots composing these rows considerably smaller than those of the dorsal surface.

Dentition as in fig. 1, *a*, seen from the outer side. Lower jaw massive and deeper than the upper one, the first tooth extremely large; upper jaw with the inner series consisting of 3 teeth, the distal one large, the middle

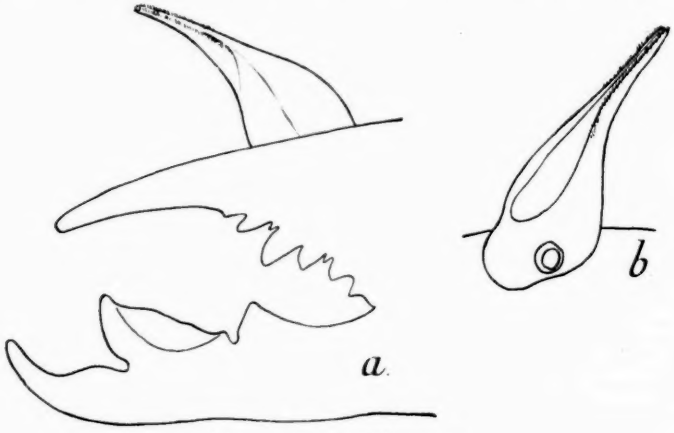

FIG. 1.—*Biton crassidens* n. sp.

moderate, the proximal one small, the two proximal ones nearer to each other than to the distal one.

Flagellum as in fig. 1, *a*, seen from the outer side; seen from the inner side, fig. 1, *b*, there is along its upper (anterior) margin an oval-shaped opening narrowing distally to form a fine canal continuing to the apex, the sides of which are bordered with fine hairlike spicules; the surface of the flagellum on its inner side with fairly well-defined striations.

Spination.—Headplate with some strong apically cleft spines; mandibles dorsally with more numerous and stronger spines in its distal half; metatarsus of palp armed ventrally with 3 blunt-tipped spines on the outer side, 1 distal spine on the inner side; femur, tibia, and metatarsus of palp ventrally with some very long setae on their inner sides, those of the metatarsus especially stout basally; second abdominal sternite with 7 large modified hairs on each side arranged in two irregular rows; the tips of these hairs enlarged and pear-shaped or roughly quadrate, as in *B. bechuanica*, Kraepelin (see Roewer, *loc. cit.*, Lief. 1, fig. 112, p. 129).

Dimensions.—Total length 14·2 mm., palp 13·2 mm., headplate + mandible 5·3 mm.

Genus BITONELLA Roewer.

Bitonella, Roewer, C.Fr., 1933. Bronn's Klass. u. Ord. des Tierreichs, Band V, Abt. 4, Buch 4, Lief. 3, p. 405.

Bitonella roeweri n. sp.

(Fig. 2.)

1 ♀, 1 ♂. Pemba, North Rhodesia.

♂. *Colour.*—Mandibles yellow with an ill-defined median and lateral stripe, the median one vanishing proximally, the lateral one distally;

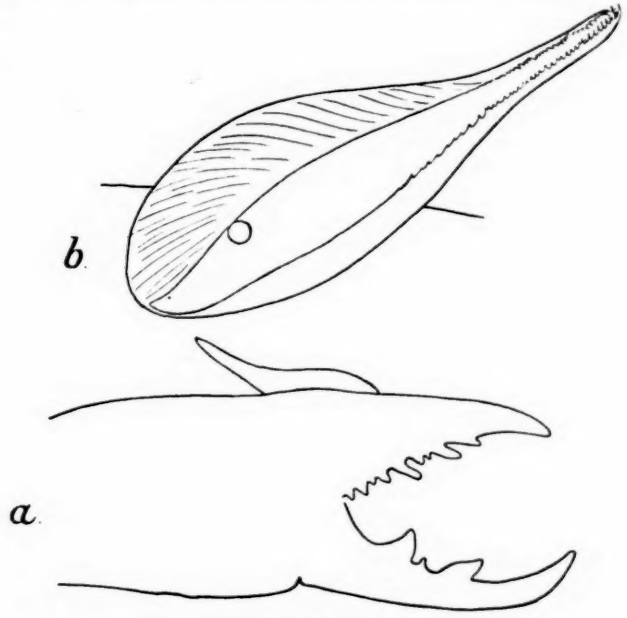

FIG. 2.—*Bitonella roeweri* n. sp.

headplate infuscated violet, a roughly ovate marking in the middle yellow; tergites of abdomen with 3 narrow stripes composed of a violet fleck in each segment, ventral surface uniformly yellow without lateral stripes; palp with the apical half of femur and distal segments infuscated violet, metatarsus and tarsus a little darker than the rest, the joints and under

surfaces of the infuscated segments considerably lighter; femur of leg III slightly infuscated, femur and tibia of leg IV infuscated, especially the apical half of femur, legs otherwise a uniform yellow.

Dentition as in fig. 2, *a*, seen from the outer side; inner series consisting of four teeth, the first and third large, the second and fourth small.

Flagellum as in fig. 2, *a*, seen from the outer side; seen from the inner side and enlarged, fig. 2, *b*, there is a large opening from near the base to the tip, fringed apically with fine hairlike spicules; the upper (anterior) half of its inner surface with a number of striations; when rotated anteriorly the apex of the flagellum falls distinctly short of the fang-tip of the dorsal jaw.

Spination.—Headplate with a thick cluster of long setae on and at the sides of the ocular tubercle, posterior to this cluster comparatively few and weak setae; mandibles above with long and strong setae which are numerous as far anteriorly as the rotatory centre of the flagellum. Femur of palp with 4 long and strong setae on its inner side ventrally, these increasing progressively in size distally, a fifth seta on the inner dorsal surface situated a little posterior to the distal seta of the ventral series and equal to it in size; tibia with 4 pairs of weaker but longer setae on its ventral surface; metatarsus with 5 pairs of spines on its ventral surface, the two proximal pairs slenderer and more pointed than the others. Second abdominal sternite with 9 modified hairs on each side, shaped as in those of *B. ovambica* Lawr. (see Roewer, *loc. cit.*, Lief. 3, fig. 277, c_2, p. 395).

Dimensions.—Total length 22 mm.

♀. *Colour* as in ♂, the three stripes of the tergites, however, almost obsolete. Dentition robust, the first main tooth smaller than the second but larger than the single intermediate tooth; inner series consisting of four teeth, the first largest, the second minute; lower jaw with 1 intermediate tooth.

Spination.—Headplate and mandibles with much weaker and slenderer setae than in the ♂; femur of palp with a rather irregular row of 5 spiniform setae on its ventral inner surface, weaker than those of the ♂, the two distal ones close together, a sixth seta on the inner dorsal surface at the level of the penultimate seta; tibia of palp ventrally with a double row of 3 long strong spiniform setae, very noticeably stouter than the corresponding structures in the ♂; metatarsus ventrally with a double row of 5 spines, the apical outer and three distal inner ones short and blunt tipped, the remainder pointed and considerably longer.

Dimensions.—Total length 25 mm.

Genus BLOSSIOLA Roewer.

Blossiola, Roewer, C.Fr., 1933. Bronn's Klass. u. Ord. des Tierreichs, Band V, Abt. 4, Buch 4, Lief. 3, p. 359.

Blossiola lapidicola n. sp.

(Fig. 3.)

9 ♂♂, Bowiesdorp, Little Namaqualand.

Colour.—Headplate and mandibles yellow, appendages uniformly yellow, abdomen light brown.

Dentition as in fig. 3, weakly developed and without strong pointed teeth as in allied forms such as *setifera* and *falcifera*; the anterior tooth of the lower jaw obsolete, with a transparent lamina on the outer side of the jaw; inner series of the upper jaw consisting of 3 teeth, the distal one largest and a little further from the middle one than the middle one is from the proximal.

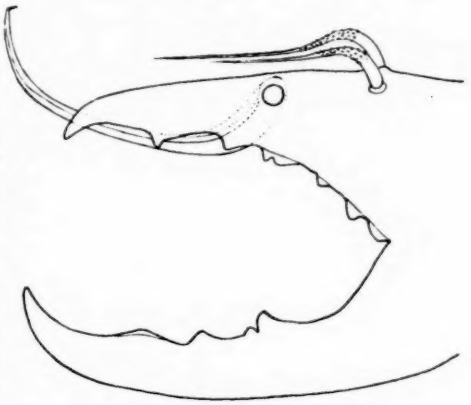

FIG. 3.—*Blossiola lapidicola* n. sp.

Flagellum as in fig. 3, seen from the outer side; when rotated forwards the tip of the flagellum exceeds the apex of the dorsal jaw by considerably less than half its own length; flagellum slender and tapering regularly, the apex with a fine but distinct needle-like process.

Spination.—Headplate and thoracic segments with strong short spines; mandibles above with some strong apically cleft spines. The distal spiculated bristles of the mandible two in number, arising near the dorsal edge of the jaw at a point considerably posterior to the rotatory centre of the flagellum, the one on the outer side very slightly in advance of the one on the inner side, the inner bristle longer than the outer one; these bristles remarkably stout at their bases, tapering rather suddenly distally, both having their middle portion armed with small scale-like spicules, their apices and bases perfectly smooth. The outer side of upper jaw with an irregular row of simple bristles, more or less parallel to the dental series and varying in size, the most distal one situated just below the rotatory

centre and armed with a few spicules which are much less distinct than those of the dorsal bristles; inner surface of upper jaw with numerous feather bristles, the three most distal ones stronger than the others, forming a group slightly in advance of them. Metatarsus and tarsus of palp irregularly clothed with slender unilaterally ciliated hairs cleft at their apices (fig. 9, *a*); tibia with 4 spines on its inner ventral surface, the basal one long, slender, and apically cleft, metatarsus similarly with 3 spines, the basal one weaker than the others; all the spines smaller and weaker than in allied species. Second abdominal sternite with 3 long sickle-shaped hairs on each side.

Dimensions.—Total length 12 mm.

This species differs from the allied species of Hewitt's Group I in having the flagellum differently and more strongly curved, in the weaker dentition, and in the two distal bristles of the dorsal jaw being situated close to each other. In these characters all nine specimens show a remarkable degree of constancy.

Blossiola rosea n. sp.

(Fig. 4.)

1 ♂, Aughrabies Falls, Orange River.

Colour.—Headplate yellow; legs yellow, tinted with pink, the fourth pair more so than the others; palps yellowish brown; abdomen without pattern, the dorsal surface a pretty rose pink, the ventral surface lighter.

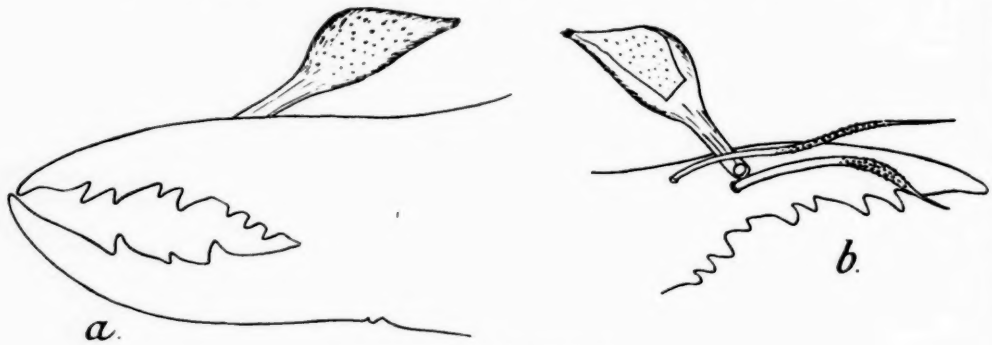

Fig. 4.—*Blossiola rosea* n. sp.

Dentition as in fig. 4, *a*, seen from the outer side; fig. 4, *b*, seen from the inner side; inner series consisting of 3 teeth.

Flagellum seen from outer side (fig. 4, *a*), with a pointed pear-shaped capsule armed on its outer surface with small triangular spicules; seen in

the dry condition the capsule has a large trapezoidal opening on its inner surface (fig. 4, *b*); stalk of the flagellum unusually long, when the organ is rotated forwards the tip slightly surpasses that of the upper jaw.

Spination.—Inner surface of upper jaw with two spiculated bristles, the most distal of these with its insertion just below the rotatory centre, much stouter than any of the remaining bristles of the jaw; the proximal bristle with its insertion situated considerably posterior to the rotatory centre and a little more dorsally than the distal bristle; it is longer and more sinuous but much less stout than the distal bristle, being nevertheless stouter than the remaining bristles of the jaw; inner surface of the upper jaw with a row of stout feather bristles parallel to the dental series, the two most distal ones inserted rather posterior to the row and forming a group between it and the large anterior spiculated bristle; the distal bristle of the parallel series of simple bristles on the outer surface not different from the others. Palps spined only on the inner side of its ventral surface, the spines compared with other species weak and invisible to the naked eye; femur with at least 2 strong spines in its proximal half, tibia with 4 moderate spines, the 2 proximal ones longer than the others, metatarsus with 3 very weak spines; metatarsus and tibia of palp with unilaterally ciliated hairs. Second abdominal sternite with 2 long, moderately curved, fleshy hairs on each side.

Dimensions.—Total length 8 mm., palp 8 mm.

Blossiola longipalpis n. sp.

(Fig. 5.)

1 ♂, 2 ♀♀, Kamanyab, Kaokoveld, South West Africa.

♂. *Colour.*—Headplate yellow, appendages yellow except the distal half of metatarso-tarsus of palp, and distal half of femur IV, these lightly infuscated.

Dentition as in fig. 5, *a*, seen from the outer side, weakly developed and not clearly defined, the spaces between the larger teeth tending to be rather irregularly serrated; inner series consisting of 3 teeth, the two distal ones larger than the largest tooth of the main series, the first (anterior) tooth a little larger than the second, the third quite small.

Flagellum as in fig. 5, *a*, seen from the outer side; fig. 5, *b*, seen from the inner side; the oval portion of the capsule open on by far the greater part of its inner surface, not frayed at the edges, its outline evenly defined.

Spination.—Mandibles and headplate with some long, fairly stout, apically cleft setae. Upper jaw dorsally without spiculated bristles, the two distal bristles, however, a little stouter than the remaining ones, the more anterior of these passing laterally to the flagellum and longer than

the posterior one which passes the flagellum on its inner side; the inner series of feather bristles parallel to the dental row, terminating with two stout bristles which form a group slightly anterior to the remainder. Tibia and metatarsus of palp without true spines, unilaterally ciliated hairs

FIG. 5.—*Blossiola longipalpis.*

present. Second abdominal sternite with 3 modified hairs on each side, these long, slender, and very little stouter than the remaining hairs of the segment, from which they are not easy to distinguish.

Dimensions.—Total length 7·7 mm., palps about 10 mm.

Blossiola orangica n. sp.

(Fig. 6.)

1 ♂, Aughrabies Falls, Orange River.

Colour as in *B. hessei*, the infuscation less clearly defined, not forming a pattern.

Dentition as in fig. 6, seen from the outer side, differing from *hessei* in the shape and smaller size of the distal tooth of the lower jaw.

Flagellum as in fig. 6, seen from the outer side, the distal curve produced somewhat further than in *hessei*, the apex narrowing rather suddenly.

Spination as in *hessei*, both tibia and metatarsus of palp with 3 stout blunt-tipped spines on their inner ventral surfaces; these spines in *hessei* are present on the metatarsus as well as on the tibia, though this is not stated in the description of the type; in both species they are strong and blunt-tipped, not setiform as mentioned in the description of *hessei*, Ann. S.A. Museum, vol. xxix, pt. i, p. 174. The modified hairs of the second abdominal sternite resemble those of *hessei* in being long cylindrical structures, scarcely stouter than the surrounding hairs of the segment.

Dimensions.—Total length 9·4 mm., palp 11·6 mm.

This species is evidently closely related to *hessei*, but differs from it in the dentition of the lower jaw.

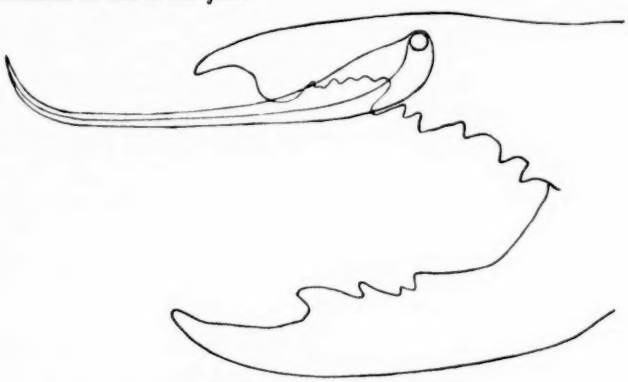

FIG. 6.—*Blossiola orangica* n. sp.

Blossiola falcifera brachygnatha n. var.

(Fig. 7.)

1 ♂, Salisbury, Rhodesia.

Colour.—Mandibles infuscated reddish brown with very faint indications of two stripes, headplate with deeper reddish-brown infuscation, a lighter patch in the middle and one on each side of the ocular tubercle; appendages faintly infuscated, the palps more so; tergites reddish, the anterior darker than the posterior ones, sternites uniform yellow.

Flagellum and dentition as in fig. 7, seen from the outer side. This variety differs from the type in having the distance between the first tooth and fang-tip of the dorsal jaw distinctly shorter than the distance between the first tooth and the fourth tooth.

Spination.—Metatarsus of palp with 2 inner spines on its ventral surface, tibia similarly with 2 spines and a stout spine-like seta cleft at its apex, femur without spines. Second abdominal sternite with 3 modified hairs on each side.

Dimensions.—Total length 8·8 mm.

Blossiola falcifera longicornis n. var.

(Fig. 8.)

1 ♂, Outjo, South West Africa.

Colour.—Headplate, mandibles, and appendages yellow, abdomen ashy grey (palps, first and fourth legs missing).

Dentition as in fig. 8, seen from the outer side, resembling that of *falcifera* except that the distance between the first tooth and the fang-tip of the upper jaw is almost 1½ times that between the first and fourth tooth.

Flagellum as in fig. 8, seen from the outer side, longer than in *falcifera*, slender and provided at its apex with a minute hook; when rotated for-

FIG. 7.—*Blossiola falcifera brachygnatha* n. var.

wards the flagellum exceeds the fang-tip by a little more than half its own length.

Spination.—Upper jaw with two distal spiculated bristles, the anterior one situated on the dorsal edge, the posterior one slightly below the dorsal edge on the inner side, both bristles tapering suddenly near their apices, the anterior one reaching to about half-way between the apex of the jaw and the first tooth, the posterior bristle a little shorter. Outer side of upper jaw with a row of simple bristles varying remarkably in size, more or less parallel to the dental series, the distal bristle considerably stouter than the rest, its insertion just below the rotatory centre, blunt-tipped and

roughened near its apex. Inner side of upper jaw with a row of feather bristles, 3 of these stouter than the remainder and forming a group well in advance of the row near its distal extremity. Second abdominal sternite with 2 modified hairs on each side.

Dimensions.—Total length 9 mm.

This variety differs from the type in the longer and more slender flagellum, and in the distance between the first tooth and fang-tip being almost $1\frac{1}{2}$ times that between the first and fourth tooth, while in the typical *falcifera* it is about equal, according to Roewer's figure of the type in Bronn's Klass. u. Ord., Bd. V, Abt. 4, Buch 4, Lief. 3, p. 360, fig. 262, *a*. If this figure is correct, then that of Kraepelin, which shows only one dorsal spiculated bristle in the upper jaw, is incorrect. I do not consider that the extremely slight differences between my variety *transvaalica* and the typical form of *falcifera* as figured by Roewer justify the retention of *transvaalica* as a distinct variety, and it therefore falls away; when the description was drawn up it was assumed that the proportions of Kraepelin's figure were correct. While the specimens from Weenen, Natal, named *B. falcifera dolichognatha* by Hewitt (Ann. Durban Mus., vol. v, pt. iii, p. 10) are probably a good variety, they do not agree with the author's original figure of the type *dolichognatha* from Douglas; this figure (Ann. Transv. Mus., vol. v, pt. ii, p. 58, fig. 10, *b*) when compared with the figure given by Roewer of Kraepelin's type suggests that these specimens from Douglas are typical *falcifera*, while those from Quibis (*loc. cit.*, p. 58, fig. 10, *a*) should be classed as a variety thereof. It seems that many closely allied forms of *falcifera* occur throughout Southern Africa; as further aids to their classification I suggest the use of such characters as (i) the dorsal spiculated bristles, (ii) the distance between the first tooth and fang-tip as compared with the distance between

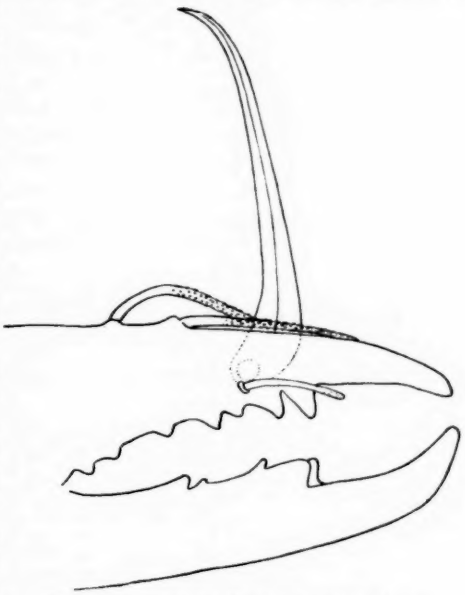

Fig. 8.—*Blossiola falcifera longicornis* n. var.

the first and fourth tooth, (iii) the terminal bristle of the series parallel to the dentition on the outer side of the jaw; this bristle may be enlarged or normal, spiculated or smooth, with a blunt or finely tapering apex.

The following is a key to the males of the species of Hewitt's Group A characterised by the long and slender flagellum, which is widest near its base and tapers more or less gradually to the apex:—

1. Dorsum of upper jaw without spiculated bristles, the distal bristle similar to the remaining bristles . . . . . 2.
   Dorsum of upper jaw with 1 or 2 distal spiculated bristles . . . . 4.
2. Upper jaw deeper than lower jaw, dorsal margin of flagellum S-shaped *maraisi.*
   Lower jaw deeper than upper jaw, dorsal margin of flagellum almost straight . 3.
3. Distance between first tooth and fang-tip of lower jaw equal to distance between first and second tooth . . . . . *hessei.*
   Distance between first tooth and fang-tip of lower jaw greater than distance between first and second tooth . . . . . *orangica.*
4. Upper jaw with 1 distal spiculated bristle . . . . . 5.
   Upper jaw with 2 distal spiculated bristles . . . . . 8.
5. Upper jaw with a small tooth on its dorsal edge anterior to the flagellum *echinata.**
   Upper jaw without such a tooth . . . . . 6.
6. Lower jaw with a short medial keel near its apex . . . *karrooica.*
   Lower jaw without a medial keel near its apex . . . . . 7.
7. First tooth equidistant from the second tooth and fang-tip of the dorsal jaw *filicornis.*
   First tooth much nearer to the second tooth than to the fang-tip of the dorsal jaw . . . . . *setifera.*
8. The two distal spiculated bristles arising close together on the dorsal edge *lapidicola.*
   The two distal bristles well separated . . . . . 9.
9. Flagellum long, distance between first tooth and fang-tip greater than that between first tooth and fourth tooth . . . . . *falcifera longicornis.*
   Flagellum long, distance between first tooth and fang-tip less than that between first tooth and fourth tooth . . . . . *falcifera brachygnatha.*
   Flagellum shorter, distance between first tooth and fang-tip about equal to that between first tooth and fourth tooth . . . . . *falcifera falcifera.*

* The distal dorsal bristle practically without spicules, these exceedingly minute.

Remarks on the Genus Blossiola.

(Fig. 9.)

Hair Structures of the Palp.—While examining the palpi of various species of this genus under low power of the microscope it was noticed that many of the hairs of the metatarsus were provided with a lateral row of minute cilia-like spicules, a modification which seems to have escaped the notice of writers on the tactile and sensory hairs of this Order. These hairs are most numerous on the tarsus and metatarsus, but also occur on

the tibia, the femur being devoid of them; they are not confined to the ventral surface or to any specific area, but occur over the general surface of these three segments. The spicules of these hairs are always arranged in one or two rows extending from near the base of the hair to near its apex, but only on one side of the hair, the proximal side or that nearest the base

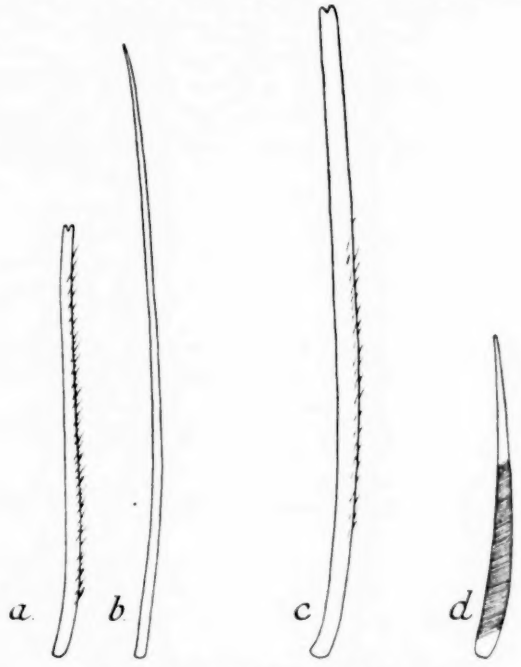

FIG. 9.—Hairs on the palp of *Blossiola* species.

of the palp. In *Blossiola lapidicola* hairs scraped from the metatarsus and mounted appear as in fig. 9, *a*; they are intermixed with long fine needle-like and perfectly smooth hairs, fig. 9, *b*; the same type of ciliated hair as in fig. 9, *a* is found in the following species: *maraisi*, *rosea*, *falcifera*, *hessei*, *echinata*, *litoralis*, *grandicornis*. In *alticursor* and *laminicornis* the hairs are considerably thicker, while the spicules are proportionately shorter and weaker (fig. 9, *c*). In *namaquensis*, *karrooica*, and *unguicornis* the spicules are present but very weak; in *laticosta* and *crepidulifera* they are so minute as to be almost invisible under low power of the microscope though distinct when high power is used. In *spinicornis* they are completely absent; in this species the hairs are short and stout but finely pointed, and are provided

in their basal half or two-thirds with fine oblique striae only visible under high power of the microscope (fig. 9, *d*).

These ciliated hairs of the palp are found only in males of the species, in the females they are completely absent. I have further examined the palpi of the following genera of Solifugae: *Biton* (*Daesia*), *Melanoblossia*, *Hemiblossia*, *Heteroblossia*, *Ceroma*, and *Lipophaga*, but find no structures in any way similar to those described above. I conclude that these hairs are peculiar to the genus *Blossiola* and presumably correspond to the short feather-like hairs of the scopula in *Solpuga*, though not limited to a well-defined area as in that genus. They are, as far as I am able to observe, confined to the palpal segments, not occurring on any of the other appendages or segments of the body. The fact that these hairs have lateral branches or spicules is not in itself peculiar, but I do not know of any other type of hair in South African Solifugae which is unilaterally branched or spiculate, and then always on its proximal side.

Spination of the Palp.—The species tabulated below are male type specimens from the various South African Museums which have been examined with regard to the arrangement of the palpal spines. The left-hand number in each column represents the outer or lateral spines on the ventral surface of the segment in question, and is separated fromthe number representing the inner or medial spines by a hyphen; the numbers in brackets are spines which are long, slender, and finely pointed or slightly cleft apically, as distinguished from those which are short, stout, and bluntly rounded apically. In the fourth column the numbers of modified hairs (ctenidia) occurring on the second abdominal sternite, are given.

Roewer in several instances, e.g. *litoralis*, *unguicornis*, states in his key to the genus (*loc. cit.*, pp. 359–369) that spines are found on the lateral as well as the medial side of the metatarsus; this is not the case in any of the South African types I have examined, and I think rarely if ever occurs in this genus, the spines being always situated on the medial or inner side and not arranged in pairs; specimens of *falcifera* in our collection, including nine males, have in all cases the ventral surface of the tibia spined on the inner side only, as in the metatarsus, the spines not being arranged in pairs as stated by Roewer. The femora of *Blossiola* species, if armed at all, are spined on the inner side only.

Spination of the Legs.—The following type species (male specimens) have the ventral spination of tarsi II and III arranged 1, 2, 2, 2 as in Roewer's account of the genus (*loc. cit.*, p. 359, p. 357, fig. 260, *b*): *hessei*, *orangica*, *rosea*, *lapidicola*, *longipalpis*, *karrooica*, *alticursor*, *spinicornis*, *namaquensis*, *grandicornis*. The position of the proximal pair of spines varies in different species in its relation to the middle pair, being sometimes twice as far from the middle pair as the middle pair is from the distal pair.

Species.	Femur.	Tibia.	Metatarsus.	Second abdominal sternite.
hessei . . .	0—0	0—3	0—3	3—3
orangica . . .	0—0	0—3	0—3	3—3
rosea . . .	0—2	0—2 (2)	0—3	2—2
lapidicola . .	0—(2)	0—3 (1)	0—2 (1)	3—3
longipalpis . .	0—0	0—0	0—0	3—3
echinata . . .	0—4	0—4	0—3	3—3
karrooica . .	0—3	0—3	0—2 (1)	3—3
crepidulifera . .	0—2	0—4	0—0	3—3
alticursor . .	0—0	0—3 (1)	0—3	3—3
spinicornis . .	0—1	5—5	0—3	3—3
tricolor . . .	0—3	3—4	0—3	3—3
namaquensis . .	0—0	0—3	0—3	2—2
laminicornis . .	0—4	0—4	0—2	2—2
grandicornis . .	0—5	0—5	0—1	2—2
unguicornis . .	0—1	0—3 or 4	0—3	2—2
laticosta . . .	0—2	0—4	0—3 or 4	3—3
maraisi . . .	0—2	0—3	0—3	2—3
litoralis . . .	0—1	0—4	0—3	3—3
filicornis . .	0—(1)	0—3	0—3	2—2

Genus Melanoblossia Purcell.

Melanoblossia tridentata n. sp.

(Fig. 10.)

1 ♂, Kimberley.

Colour.—Headplate olive brown; appendages light brown with an olivaceous tinge; tergites deep olive brown, a lighter median stripe; sides blackish; sternites yellow with a greenish tinge, posterior apex of abdomen blackish. This colouring probably differs from that of the living animal, the specimen having been for some years in alcohol.

Dentition as in fig. 10, *a*, seen from the outer side; jaws, especially the upper one, strongly compressed laterally, the dorsal and ventral margins of the upper jaw with a blade-like keel or crest which is much thinner than the rest of the jaw; inner surface of upper jaw with a wide and shallow but very distinct groove running backwards from the anterior notch near the fang-tip; lower jaw seen from directly above with a slight sigmoid flexure; only three teeth present, these large, equal sized, equally spaced, and situated in the basal third of the upper jaw.

Flagellum as in fig. 10, *b*, seen from the inner side, consisting of a basally broad rod tapering regularly to a fine point; this rod apparently not later-

ally compressed, clothed with soft hairs, and directed at an angle of between 30° and 45° to the group of 3–5 setae at its base; these setae with much stronger accessory hairs than in the case of the flagellum proper.

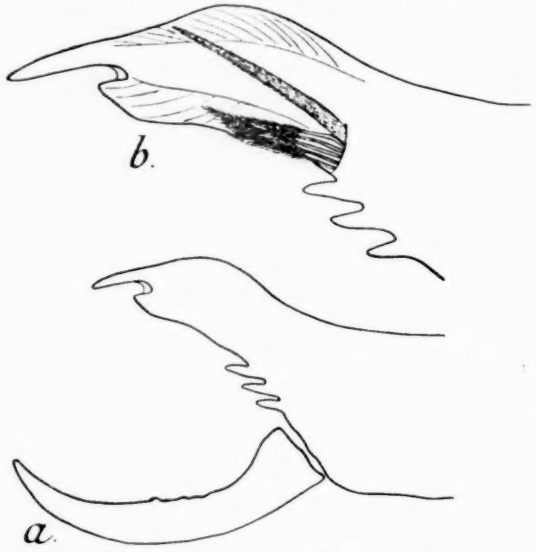

FIG. 10.—*Melanoblossia tridentata* n. sp.

Spination.—Headplate quite smooth except at the back and sides, mandibles with some long and strong dorsal spines; femur, tibia, and metatarsus of the palp with a very irregular row of long setae on each side of the ventral surface, those of the tibia longest and strongest. Spination of legs II and III difficult to define with accuracy, apparently as follows: Metatarsus II with 2, 2, 2, 2, 2, III with 1, 1, 2, 2, 2 lateral spines; tarsus II with 1, 2, 2, 2, 2 ventral spines, the first pair more laterally situated than the others, III with 1, 2, 2, 2 ventral spines. Second abdominal sternite with 5–7 long cylindrical modified hairs, some considerably stouter than the others.

Dimensions.—Total length 6·5 mm.

Melanoblossia namaquensis n. sp.

(Fig. 11.)

1 ♂, 10 ♀♀, Bowiesdorp, Little Namaqualand.

♂. *Colour.*—Headplate, mandibles, palp, almost black, with a purplish tinge; tergites with a fairly broad brown median band, almost parallel-

sided but constricted at about the level of leg III, then widening just behind the headplate; a very light metallic-blue band on each side of the median band, its width anteriorly about half that of the median band, decreasing considerably posteriorly; sides blackish; sternites brown, a

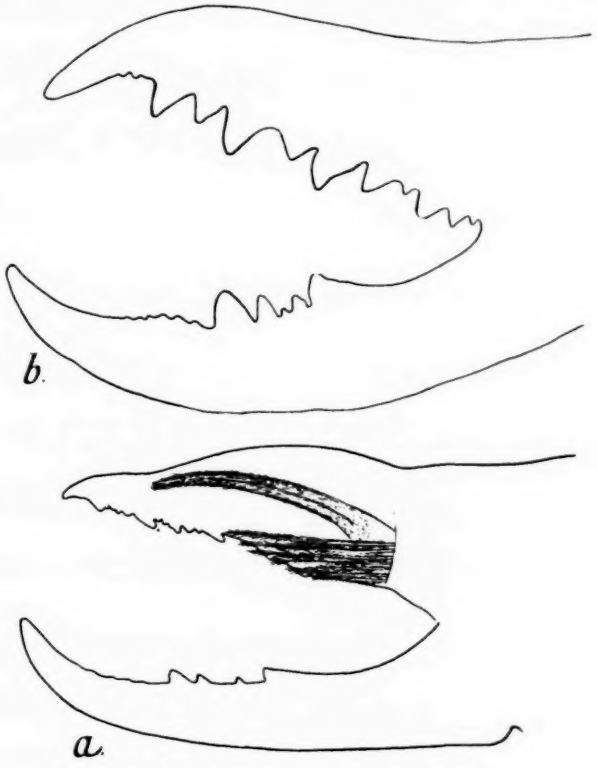

FIG. 11.—*Melanoblossia namaquensis* n. sp.

little lighter in the middle; legs with the proximal segments and femora purplish-brown, contrasting strongly with the distal segments which are yellow, except leg I, the whole of which is moderately infuscated, the tarsus a little more so; malleoli with their edges faintly infuscated.

Dentition as in fig. 11, *a*, seen from the inner side, the smaller teeth granuliform, the larger ones recurved; the jaws strongly compressed laterally, curved outwards at an obtuse angle to the main axis of the mandible.

Flagellum as in fig. 11, *a*, seen from the inner side, consisting of an ill-defined hairy rod lying in a groove on the inner surface of the upper jaw, reaching as far as the second main tooth; the hairs covering the flagellum very fine, shorter in its proximal than in its distal half; below the flagellum 6–8 bristles clothed with fine soft hairs, the longest bristle reaching the most posterior of the main teeth of the jaw.

Spination.—Mandibles above with some long apically cleft spines; headplate with these and in addition numerous much shorter and weaker setae; femur of palp on its inner ventral surface with 3–4 long spiniform setae, distinguished from the other setae of the segment by the knob-like chitinous enlargements from which they spring, tibia similarly with 2 very long spiniform setae about twice as thick at their bases as those of the femur, metatarsus with 1 or without setae; tarsi II and III with 1, 2, 2, 2 spines ventrally, metatarsi II and III with 5 spines dorsally not forming a regular row; tarsus IV indistinctly 2-jointed, the distal joint considerably shorter than the proximal one and not movably articulated with it.

Dimensions.—Total length 9·4 mm.

♀. *Colour* as in the ♂, the brown median band of the tergites a little lighter, especially in the middle, the light lateral bands a little wider than in the ♂, sternites distinctly lighter; malleoli with darker edges than in the ♂.

Dentition as in fig. 11, *b*, seen from the outer side.

Spination as in the ♂, second abdominal sternite without modified hairs.

Dimensions.—Total length 13·4 mm.

This species is closely related to *M. globiceps* Purcell.

Genus Lawrencega Roewer.

Lawrencega, Roewer, C.Fr., 1933. Bronn's Klass. u. Ord. des Tierreichs, Bd. V, Abt. 4, Buch 4, Lief. 3, p. 342.

Lawrencega hewitti Lawrence.

The spination of legs II–IV of the type is as follows:—

Metatarsus.	Tarsus.
II. 1.1.2.2.2 lateral.	1.2.2.2 ventral.
III. 3 lateral, 3 dorsal, the lateral spines not opposing, but alternating with the dorsal spines.	1.2.2.2 ventral.
IV. 1.2.2 ventral.	2.2.2.2.2 ventral.

The spination of metatarsus II is not given with full confidence of its correctness, some of the spines having been broken off.

New Records.

Biton schreineri Purcell.

The South African Museum has, in addition to the types, 25 specimens (16 ♂♂, 9 ♀♀) of this species from the following localities: de Aar, Smithfield, Beaufort West, Fraserburg, Carnarvon, Willowmore. In all of these the fourth tarsus is distinctly 4-jointed and the lower jaw has 3 teeth. As will be seen from the above records the species occupies a fairly large area in the central inland of South Africa; *Broomiella lineata*, of which the Museum does not possess an example, has evidently an extremely limited distribution which slightly overlaps that of *B. schreineri*; *Broomiella lineata* may possibly be a monticolous form and, like the monticolous species of the Western Cape, be only found at considerable altitudes over a small distributional area. In addition to the characters of spination and dentition there appears to be a distinction in the size of the two forms.

Biton rhodesiana Hewitt.

This species seems to be the only one occurring in the Transvaal, where it is, however, fairly common; the Transvaal Museum has 10 specimens collected by Messrs. Fitzsimons and van Son from the following localities: Salt Pan, near Pretoria; Blyde River, Eastern Transvaal; Olifants River, Eastern Transvaal.

Bitonella striata Lawrence.

1 ♂, 2 ♀♀, Upington, J. White.

10 ♂♂, Otjiwarongo, South West Africa, J. S. Brown.

Blossiola spinicornis Lawrence.

1 ♂, Nurugas, near Grootfontein, South West Africa, R. W. E. Tucker.

1 ♂, Tsumeb, South West Africa, R. F. Lawrence.

Dr. Roewer states that, according to my figure of the type, the species has only two teeth in the lower jaw; Dr. Roewer must have been referring to a different figure, as my figure 49, Ann. S.A. Mus., vol. xxv, pt. ii, clearly shows three teeth.

Blossiola alticursor Lawrence.

3 ♂♂, 1 ♀, Wellington Mts. at 5000–6000 feet altitude, K. H. Barnard and R. F. Lawrence.

In his monograph of the Solifugae, Dr. Roewer has reported a male specimen of *alticursor* as occurring at Gaberones, Bechuanaland; I have no hesitation in saying that this record must be incorrect. *Blossiola alticursor* is a species with a very limited distribution, as have all the

monticolous species of Solifugae living at high altitudes in the Western Cape Province, where environmental conditions are peculiar and very different from those of the level plateaux of the interior.

Blossiola echinata Purcell.

1 ♂, Smithfield, R. Kannemeyer.

Blossiola crepidulifera Purcell.

1 ♂, Montagu, R. W. E. Tucker.

Blossiola hessei Lawrence.

1 ♂, between Murraysburg and Victoria West, V. Fitzsimons.

Heteroblossia o'neili Purcell.

1 ♂, 2 ♀♀, Smithfield, R. Kannemeyer.

Melanoblossia braunsi Purcell.

1 ♂, Matjesfontein, S. Cronwright-Schreiner.

Zeriassa cuneicornis Purcell.

1 ♂, Otjiwarongo, South West Africa, J. S. Brown.

NOTES ON NOMENCLATURE IN SOME MEMBERS OF COMPOSITAE.

By Margaret R. Levyns.

(Read September 19, 1934.)

While working at Kew a few months ago the writer took the opportunity of going into the question of nomenclature in certain genera of Compositae. Two of these genera, *Stoebe* and *Elytropappus*, contain species of ecological importance, and as it was probable that some specific names were being applied wrongly, an early investigation seemed desirable. The full results of the research will not be available for publication for some time, but as errors in nomenclature have been clearly established in certain cases an account of these is given now.

Stoebe L.

Stoebe tortilis DC.

This species was founded by De Candolle in 1837 on a specimen collected by Ecklon at Uitenhage. Harvey in 1865 added Zeyher 2920 from the Van Stadensberg. I have seen Ecklon's specimen, now housed in Geneva, and Zeyher's specimen at the South African Museum. Both specimens are poor, and from their appearance it is likely that the flowering season was almost over when their collection was made. In both cases, however, one ligulate floret was obtained from heads where tubular florets predominated. The presence of these ligulate florets shows clearly that these plants have been placed in the wrong genus. Both specimens belong to *Disparago ericoides* Gaertn., a species in which the capitula are normally one-flowered. *Stoebe tortilis* DC. has therefore no existence.

Stoebe cinerea Thunb.

At present this name is applied to a heterogeneous collection of plants. The popular name of many of these plants is slangbos, and as the plant known as slangbos in the Transvaal is proving as aggressive there as our Rhenoster bush is here, it is important that the correct name of this plant

should be ascertained as soon as possible. The problem is by no means solved, but two points are clear:

(a) *Stoebe cinerea* Thunb. is synonymous with *Seriphium cinereum* L. I have seen Linné's actual specimen, which is not one of the plants commonly called *S. cinerea*, but is a plant common on the eastern slopes of Table Mountain, with a restricted geographical range elsewhere. Burchell 805, 859, 482, and 8189 are this. So are Tyson 2375, MacOwan 1007, and Bolus 3962. This plant is quite distinct from, though allied to, the plants at present known as slangbos.

(b) *Stoebe plumosa* Thunb. is synonymous with *Seriphium plumosum* L. In the Flora Capensis this name is treated as a synonym for *S. cinerea* Thunb. There is a good specimen of this plant in Linné's herbarium, and it is one of the many plants known as slangbos. It is fairly common in the south-western districts, and may be easily recognised by its pale grey, plume-like branches. Burchell 733, 4947, 8160, Bolus 4757, and Wolley Dod 2613 are *S. plumosa* Thunb.

The problems that still remain to be solved are: How many good species still remain in the slangbos complex? Which, if any, of the numerous names at present treated as synonyms of *S. cinerea* belong to these species?

Disparago Gaertn.

Disparago Kraussii Sch. Bip.

This species was founded by Schultz Bipotinus on specimens collected by Krauss in the Zitzikama, and Drège on Sir Lowry's Pass. These specimens are allied but show certain differences. Drège's specimen is indistinguishable from *D. laxifolia* DC., and must therefore be placed under that species. Krauss's specimen is different, and the name *D. Kraussii* may be retained for this. Both specimens examined by Schultz Bipotinus are on one sheet in the herbarium at Paris. A specimen, Schlechter 2449, from Christina Bay, George, agrees with Krauss's specimen from the Zitzikama.

Disparago seriphioides DC.

This was founded on Burchell 705, collected between Salt River and Rondebosch on 31st January 1811. I have not seen this, but I have seen Burchell 706 from the Cape Flats near Salt River, collected on the same day as Burchell 705, and Burchell 829 from the Cape Flats, Rondebosch, collected on 14th February 1811. These two latter specimens are in the herbarium at Kew named *D. seriphioides*. I have examined both carefully and can find no trace of the pappus bristles said to exist on the ligulate florets. This character is the only one which separates *D. seriphioides*

DC. from *D. lasiocarpa* Cass. *D. lasiocarpa* Cass. has a densely hairy covering on the ovary of the tubular floret, and as the tubular and ligulate florets are closely associated it is possible that De Candolle mistook some of the hairs from the ovary of one floret for hairs of the pappus of the other. In view of the facts stated above I am of the opinion that *D. seriphioides* DC. has no real existence.

Disparago hoffmanniana Schlechter.

I have seen Schlechter's type specimen, No. 9801, from Genadendal. It is identical with *D. lasiocarpa* Cass. Schlechter in his description states that it differs from *D. lasiocarpa* in the absence of a pappus in the ligulate florets. In the Flora Capensis a mistake occurs in the key to the species where *D. lasiocarpa* is said to have a pappus in the ligulate florets, but in the description of the species it is correctly given as having no pappus in these florets. Thus Schlechter created the species under a misapprehension.

ELYTROPAPPUS Cass.

Elytropappus hispidus nov. comb.

Synonyms: *E. spinellosus* Cass. (1816).
Gnaphalium hispidum L.f. Suppl. (1781).

This plant was discovered by Thunberg in "Bockland" and is, in the herbarium at Uppsala, named *Gnaphalium hispidum* in Thunberg's own writing. Cassini in 1816 founded the new genus *Elytropappus* on a fragment of Thunberg's plant in de Jussieu's herbarium. According to modern rules of nomenclature the name *hispidum*, published by the younger Linné in 1781, is the correct specific name, and a new combination is therefore necessary.

Elytropappus scaber nov. comb.

Synonyms: *E. glandulosus* Less. var. *microphyllus* DC. (partly) (1837).
Stoebe scabra L.f. Suppl. (1781).

Stoebe scabra L.f. is represented in Linné's herbarium by two specimens about whose identity there can be no doubt. The plant is a very common one in the southern part of the Cape Peninsula, but, apart from one record by Rehmann near Worcester, does not appear to have been recorded outside this area. In most herbaria this plant has been named *E. glandulosus* Less., which it most certainly is not. In De Candolle's herbarium at Geneva there are four specimens named *E. glandulosus* Less. var. *micro-*

phyllus DC. Three of these are this plant. The fourth is a typical example of the true *E. glandulosus* Less.

Elytropappus gnaphaloides nov. comb.

Synonyms: *E. canescens* DC. (1837).
E. ambiguus DC. (1837).
E. glandulosus Less. var. *pallens* DC. (1837).
E. glandulosus Less. var. *ambiguus* Harv. (1865).
Seriphium gnaphaloides L. Mant. I (1770).

E. canescens is a woolly form of this species. Throughout the group of composites to which these plants belong woolly forms are of frequent occurrence, especially at high altitudes.

E. ambiguus was founded on Burchell 8242 from Sir Lowry's Pass. This specimen is at Kew and is indistinguishable from *E. gnaphaloides*. *E. glandulosus* Less. var. *pallens* DC. is also this species. There are four specimens named thus by De Candolle at Geneva, and they are identical with *E. gnaphaloides*.

Elytropappus glandulosus Less.

In the past several quite distinct plants have been placed in this species. Lessing founded the species on a specimen collected by Mund and Maire "in Tradouw." I have seen two specimens of Mund and Maire (both in Berlin). One sheet has the collectors' own label on it; the other has not, and has been labelled subsequently by someone else. The sheet with the authentic label has stalked glomerules; on the other sheet they are sessile, but otherwise the two sheets agree.

Apart from *E. hispidus* and *E. cyathiformis*, both of which are represented by one specimen only, three of the remaining four species in the genus, viz. *E. scaber*, *E. gnaphaloides*, and *E. rhinocerotis*, show similar stalked and sessile forms. In a previous paper * the writer showed that the application of Vavilov's law of homologous series in variation is of great value in any critical determination of the limits of species within a genus. Vavilov's law may be applied equally well here. The stalked and sessile characters of the glomerules occur too frequently within the genus to be of specific value, and one may therefore assume that the two specimens collected by Mund and Maire are forms of the same thing.

* "A Revision of *Lobostemon* Lehm.," and a "Discussion of the Species Problem," Journ. Linn. Soc., xlix, pp. 393–451, 1934.

This species has been found in localities ranging from the Malmesbury to the Swellendam divisions.

Elytropappus glandulosus Less. var. *longifolius* DC.

This is a much more robust plant than Lessing's type and has reflexed leaves. The species and this variety are usually quite distinct, but intermediate forms have been found occasionally. The fact that they occupy similar geographical areas is an additional reason for retaining this plant as a variety of *E. glandulosus* until further investigations have been made in the field.

VESALIUS ON CHINA-ROOT.

Extracts from the Letter of Andreas Vesalius to Dominus Joachim Roelants, written at Ratisbon, 13th June 1546.

Translated from the Latin by Benjamin Farrington.

(Read August 15, 1934.)

Introductory Note.

The treatise of Vesalius called *On China-root* is in form a letter written to his friend Joachim Roelants, a physician of Mechlin. It is a long work, occupying over sixty pages in the folio edition of the works of Vesalius edited by Boerhaave and Albinus in 1725. But of these only some ten pages are devoted to the topic which has given its name to the work: in the remaining fifty-odd pages Vesalius is concerned with the defence of the position he had taken up against Galen in his *De Fabrica Corporis Humani* published three years before. The work thus falls into two distinct parts, an introductory part of some ten pages dealing with China-root, and in the second place a long and powerful polemic directed against Galen and the Galenites, substantiating in detail the charge made in the *De Fabrica* that Galen had not described the anatomy of the human body from personal dissection of it.

In the present paper we are not concerned with the longer and more important part of this work of Vesalius, but only with the introductory pages devoted to China-root. These pages, however, are far from being devoid of interest. Vesalius was not only an anatomist. He was a practising physician who left his mark on his Art not only by his epoch-making rehabilitation of the science of anatomy, but by his estimate of the relative importance of the various branches of the healing art, and by the scientific spirit he applied to the administration of drugs no less than to the handling of the knife. His scepticism with regard to the pharmacology of his day was but part of the incipient distrust in the whole physiology of Galen which his anatomical discoveries had awakened in him. If it is due to accident that his discussion of China-root is comprised in the same letter with a renewal of his onslaught on Galen, the juxtaposition is still a happy one. The treatment of both topics is inspired by the same mood, distrust

of authority, and renewed hope in the possibility of a scientific understanding of the mechanism of the human body.

China-root, although Vesalius did not know this fact, is the root of China smilax, a relative of sarsaparilla. Vesalius could find out no more about its provenance than that it was brought to western Europe by Portuguese and other merchants, that it grew perhaps near India, perhaps in the New World, and that it was imported also into Constantinople, where a Jewish physician was trying it without much success. It was trustfully administered to sufferers from a great variety of diseases, but owing to the special circumstances of the time the highest hopes were placed on it as a cure for syphilis. Vesalius had first enjoyed the opportunity to observe the effect of the new drug when he was a student in Venice, without forming a high opinion of its powers. But latterly the treatment had leaped into sudden fame owing to its having got about that the Emperor Charles V had used it with benefit to his general health. Vesalius and other physicians of the Imperial Court were besieged with enquiries. It was under these circumstances that Vesalius wrote his account of the drug and its efficacy. From it have been excerpted for presentation here the passages of most interest and importance for the student of Vesalius. The detailed instructions for the preparation and administration of the drug have been omitted.

B. F.

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Andreas Vesalius to His Dear Friend Dominus Joachim Roelants, a Leading Physician at Mechlin.

At length I am come to Ratisbon. With me is the Venetian Ambassador, Bernard Navagerius, a singular ornament of his Republic, both on account of his remarkable knowledge in the various branches of learning and for many other reasons. Here the presence of intimate friends together with the letters that had accumulated during my absence have banished from my mind the boredom I had to undergo at Nymegen while contending, by the Emperor's command, with a difficult and dangerous disease.

It is wonderful, to be sure, what pleasure frequent letters from one's friends in various parts can bring; and the pleasure has been all the greater on this occasion as I had many letters to read through at the same time. Among the rest were two written by you, with enclosures from your son, who gives such excellent promise in our Art. You may imagine how they

delighted me, both as witnesses of your constant love and because your letters never fail to bring me news of our country's affairs and of our common studies. For this reason they must always be those I most eagerly wait for. There was further the fact that I was informed at length by your son's letters what the great champions of ancient medicine—great at least in my eyes—were doing in Paris and what the progress of our studies was there.

But while I delayed replying to your letters because I was busy and because I had to write to my people on personal matters, your further letter was brought in which you desire an account of the method in which a brew of the root called Chyna has lately been administered to the Emperor and to many in our court; my opinion on the root; and finally with what success in the restoration of damaged health we have employed it. My fellow-countryman, Antonius Zuccha, whom you commend to me in your letters for his rare charm and his notable learning, makes the same request of me in no ordinary terms. And, indeed, it is wonderful how unremittingly and earnestly the neighbouring German physicians, and those who are present at consultations in the household of their princes (*et qui in comitiis in suorum Principum familia intersunt*), keep asking me about the preparation of that decoction. They do not cease worrying me, nor put an end to their prayers and petitions, before they get the formula according to which they persuade themselves that we administer the brew. Meantime I say nothing of those who have been so eager and zealous for this knowledge that they thought right to extol the virtues of this brew to their princes to such good effect that the princes have not thought it beneath them to take up their physicians' cause with the Emperor, and to beg and pray His Highness that the whole method of administering this brew should be expounded to them by me. So great reputation and esteem was the authority of the Emperor able to give the remedy. For, if he has taken the Chyna-root decoction, he did so rather of his own accord than on the advice of Dominus Cornelius, who, since the departure of Dominus Cavallus, has been his favourite physician.

While I was still a student at Venice receiving clinical instruction under the best physicians then practising there, the root was brought thither, not without the greatest expectations and the highest praises. But in one or two cases in which it was employed it unfortunately failed. This, however, happened not so much through any fault of the drug or any ignorance on the part of those who administered it, as because it was first given to patients who in any case were near to death, and so were beyond help from the physician. The first person to whom I saw it administered had it sent to him from Antwerp along with a quack (*empirico*), who swore that he had a good knowledge of it and had successfully employed it in

Portugal. There was not a single serious sympton of syphilis from which he was not suffering, and he carried death on his face like one in the last stages of consumption. The result was that as soon as a perspiration was seen to be induced by the action of the Chyna-root and urination was at the same time stimulated, and less food than usual was given, he promptly breathed his last. His viscera, which were examined at the urgent request of his relatives and friends, were found to be in such a state that no reasonable explanation could be offered as to how the man's life had lasted as long as it did.

The second patient who was dosed with Chyna-root about the same time seemed to be in the grip of syphilis, but without any marking of the skin; and in addition to extreme bodily thinness, not to say emaciation, he had long been growing a remarkable stone in his left kidney. When he had been using the brew for ten days more or less, and when his physicians had persuaded him to refrain from it on account of the exceptional powers they believed it to possess of producing liquid (*colliquandi*) and promoting urine and sweat, he died a few days later with acute pain in the kidneys.

Accordingly, the use of Chyna-root, though rather on account of the serious illnesses of the patients than its own qualities, now began to be ridiculed and belittled by all, and then to drop out of mention. Whereupon comes another physician from Antwerp proclaiming open-mouthed that Chyna-root was the one and only heaven-sent remedy, and adding withal that there was no disease however despaired of and given over which it could not help. In him so much confidence was placed by the nobles (and he had indeed some learning to recommend him), that the Chyna-root was sent to the Bishop of Verona, who was keeping his bed with consumption and I know not what diseases beside. Before he had properly begun to use it the worthy man was translated to a higher sphere. The upshot was that all the time I was in Italy Chyna-root was absolutely cast aside. I followed my teachers and did not set much store by it. I hear also that about the same time in Burgundy a companion of my student days made use of a decoction of Chyna-root in wine, with great promises, but with such success that the name of Chyna-root has hardly been heard there from that day to this.

Last year, however, the world-famous John Baptista Gastaldus kept his bed for a great part of the winter on account of a racking pain of a nervous kind in the lumbar region, and a sort of paralysis (*ac veluti resolutionem*), together with a weakness of the stomach; and when at the beginning of spring he began to look like being restored to health, on the advice of certain friends, and when he was already convalescent, he took Chyna-root, not without beneficial results. The same, as you know, was the case with that Spanish nobleman who came from Mechlin to Brussels,

and who did more than all the rest to commend Chyna-root to very many persons. At the same time four or five sufferers from syphilis urged their physicians to try the Chyna-root on them also. And in certain cases we have seen an appreciable result. In others, however, and particularly those more seriously afflicted with the disease, we have seen far less result than we might have expected from the use of Guaiacum wood. Accordingly the Emperor, as you are aware, thought little of Chyna-root, and used a decoction of Guaiacum for his gout and poor condition.

But some people never tire of praising new remedies. Certain Spanish nobles (*primates*) and other prominent men kept preaching to the Emperor that there is no more sovran specific in all diseases than this Chyna-root, and that Guaiacum was quite abandoned in the Spains and in various parts of Italy. They backed up these assertions by producing letters from their friends. At last the Emperor became possessed of the idea of taking Chyna brew. An additional attraction was that Chyna-root was particularly recommended both as requiring to be taken for a shorter time and as being accompanied by a far more tolerable diet, one, if I may so put it, less bound down by rules, than that prescribed with Guaiacum. Thus it has come about that men at a distance, assured that the supreme emperor of the world has taken Chyna-root, hold the most extravagant opinions and make the most glowing pronouncements about this remedy, and suppose themselves to be but ill-equipped if they have not a knowledge of the method of administering the brew.

Yet, as a matter of fact, no very compelling argument can be deduced from the Emperor's case in support of the claims of Chyna-root, for the Emperor used it only for a fortnight, never adhered to one diet, and constantly changed his method of taking the decoction, and that, too, at his own discretion. It was at a time, too, when he was free from trouble with his breathing, as well as from the tortures of the gout which afflict him periodically. Yet it must be allowed that the joint where the left humerus joins the scapula, which from the year before was somewhat obstructed in the motion in which the bracchium is raised by the deltoid muscle, he now feels to be quite free; and the trouble has also been dislodged from the left leg, which from about the same time, in the neighbourhood of the malleoli and the junction of the talus with the tibia, seemed somewhat to hinder his motion and spoil his otherwise elegant beauty. Furthermore, the Emperor, on feeling better, seems to have dropped the use of the decoction merely under pressure of business and with the full intention of resuming it in the autumn under stricter conditions of attention. At present he is blessed with that health which comes to him particularly on campaign, and which, for the whole world's sake, good men ought humbly to pray that he may continue to enjoy. For you know how excellent

his health is wont to be when in the midst of the greatest physical exertions and preoccupation with affairs.

. . . . . .

A short passage is omitted here, giving further particulars of the Emperor's way of life, and making mention of two illustrious patients, Dominus de Bossu and Dominus Ludovicus Sances, Regent of Sicily, who tried Chyna-root with inconclusive results.

Translator's Note.

. . . . . .

These facts I have put together so that you may understand how far I am able to comply with your wish when you ask for a description of the method in which we administer Chyna-root. For I am not at all ashamed to reveal my ignorance to you, especially with regard to a medicine which has been given unscientifically (*citra rationem*), one might say by rule of thumb (*tanquam per manus*), and which I first ventured to administer quite recently with nothing to guide me but mere empiricism.

Up to the present, indeed, it has not been possible for me to establish certainty even with regard to the name of the root, since it is called Chyna by some, Chynna or Cyna by others, and by others again Echina and Achyna, as you write it; as if some island, or locality in India or in the New World, had given a name to it. It is imported by those who bring pepper, caryophilus, ginger, and our cinnamon, as well by the Portuguese as by those who voyage under the patronage of the Emperor. Their report is that it is gathered on seashores; and it is very probable that it comes from marshy places by the sea, as do various reeds and rush-like plants. Nay, if we carefully examine plants of this kind after they have been pulled out of the earth and broken by sailors, perhaps, or fishers, or in some other way, and have then been long tossed in the sea and at last thrown on some sandy shore, why we shall see something very like this Chyna-root. Indeed, I do not know anything to which it may more fitly be compared than to the roots of the plants, just mentioned, accidentally exposed to view in the way I have described on seashore or river-bank. The only difference is that these roots are blacker, whereas Chyna has a dullish red colour like common acorus (sweetflag), or what we call galingale. Nay, what can be more like Chyna-root than this acorus when rotten and already insipid in taste, except for the weight and the hardness? For Chyna is remarkable for its big, rough, uneven fragments, and is somewhat more wooden in texture. Yet it, too, is very fungous-like, and like the aforementioned roots is without doubt a succulent when growing, as is plain to be seen even in the dry and partly wormed state in which it reaches us. In order to conceal the rottenness and the worm merchants are apt to

cover Chyna up in the common Armenian soil (*bolo Armenio*) in use in the shops, just as they cover the reddish-coloured ginger which is exposed for sale in the shops, and especially in Antwerp.

I enquired of our common friend Gerard, seeing how studious he is in botany and in everything else, whether in his embassy to Turkey he had heard any true relation concerning Chyna-root. I got nothing from him except the fact that Chyna is also brought to Constantinople, and is used by a certain Jew with less success than his patients hope and expect. Nor could I extract any information from the merchants other than that China is found on seashores, and that the inhabitants use it in eczema (*in scabie*), just as we do sorrel (*rumex aut lapatium*). Though there are not wanting merchants who, in order to promote its sale, add solemnly that the inhabitants cure themselves of every sort of disease by a decoction of it.

For my own use, as in the case of rhubarb and all other roots, I select Chyna outstanding in weight, as succulent as it is possible for that dry wood to be, and as free as I can find it from worm or decay, that is to say, as immune as possible from the putrefaction which, owing to its very spongy and moist consistency, it might have retained during the process of drying. But however careful I may be in selecting these pieces and then in choosing from among them smooth small fragments, rather than woody and bulky ones, nevertheless I am still quite in the dark with regard both to the primary and the secondary qualities, as we call them, which prove the medicine to be endowed with the excellence it is generally supposed to have.

For if we judge these powers to derive in particular from the savour, why should we suppose them to inhere in a flat, insipid taste? For however much you chew Chyna-root and grind it under your teeth, you will not be able to detect any savour in its dry and wooden consistency. Much less, so far as its own nature is concerned, and if it have not derived it from the neighbourhood of other drugs, does it emit any smell; nor does it exhibit that oily quality which some claim to have detected in it, when you taste it or deal with it in any other way.

In cold truth it is entitled only to a fraction of the praise of Guaiacum wood. Even our native and familiar remedies might be puffed up with high praise for the very purposes for which Chyna is regarded as a supernatural specific. Everybody knows how helpful in the matter in question are the roots of the lesser and the greater centaury, rhapontic, elecampane, birth-wort (*aristolochia*), gentian, galingale, cinquefoil, sorrel, and other such herbs, including the caper-plant (if it be allowed to possess some power of astringency), not to mention the decoctions that can be made from wormwood, hyssop, mint (the text has *calimenti*, dried vine wood, which I take to be a mistake or mis-spelling for *calaminthe*), pennyroyal, wall-

germander, and finally of juniper wood, common corn (*nostrae spicae*), hazel bark, and other simples of this kind. We show ourselves as foolish as the poor sufferers themselves when we admire and employ these exotic drugs regardless of reason and the correct practice of our art.

For my part I cannot discover how Chyna-root came to have the merit ascribed to it which many have long conferred upon it, and through which now, with a sudden leap, it begins to acquire fresh fame and be extolled for new powers. It is said, to wit, that it is hot, a good aperient, a great promoter of urine and sweat, that it consumes and absorbs superfluous, unwholesome, and all other kinds of humours, and thus has been found to purify the blood and to possess soothing and cleansing properties; that at one time it keeps the bowels open, and anon, although it is a specific for urination and sweating, keeps them closed; that it is a remedy for a stomach plagued with phlegm, and banishes ailments of the liver and the spleen; that it is an effective remedy for those in torment with stone, even breaking the stone itself up; that it drives away gout, is especially helpful in leprosy, cures skin diseases, and is no common aid in fistulas, malignant ulcers, and ulcers that have defied all other treatments; that it has a miraculous curative effect in syphilis, whether recently contracted or of long standing, and that it heals sores occasioned by it as well as the scars they leave; that it banishes pain in no matter what part of the body, reduces swellings or, if they are about to suppurate, brings them to a head, opens them, cleanses them, and covers them with a wholesome scab; that it heals diseases and abscesses of the bones; that it relaxes convulsed and contracted nerves, and tones them up if they have become flaccid and weak; that it warms up nerves that are chilled and numbed by syphilis; that it makes men wasted by this disease fit again; that to their rotten bodies, all but corpses, it brings a pleasing smell; that it removes bad breath; helps those whose breathing is difficult; banishes chronic angina; drives away mental afflictions consequent upon syphilis; and stops every kind of fluxion by its invaluable aid; finally, that it has all the virtues of Guaiacum wood—nay, very many more and even mutually exclusive ones—and is accordingly to be preferred to it.

Yet all the time that flat taste I have described, without the least sign of astringency, is found in Chyna-root. However long you boil it in pure water, you can never induce any other flavour in the water than you might find result from unhusked barley or a minute portion of liquorice, though the Chyna brew has a reddish colour like dark wine, or wine that has contracted a red colour from standing a long time in a decanter. Thus, so far as its ascertainable qualities are concerned, as much might be expected from barley-water as from Chyna in the promotion of sweating and urination, and all the other powers for which the latter is so celebrated to-day.

Relying upon these arguments I conclude that, if Chyna is to be used as a remedy, the patients to whom it is best suited are sufferers from syphilis, whose symptoms are slow fever, acridity of the humours, and a generally bilious state. From the point of view of strict medical practice these are the only patients I have known to derive any real benefit from the use of Chyna. And I am sure that it was from its success in such cases that it first came into favour.

And so, my dear Joachim, since various and, I might say, diametrically opposed properties are here ascribed to Chyna, and inasmuch as those who use the decoction do sometimes attain the desired end (provided, however, they do not neglect the proper use of the drugs which necessarily accompany the use of Chyna, nor a proper system of diet), let that refuge of ours, to which assuredly we too often flee, not fail us now—I mean the recourse to recondite and hidden qualities, which we call specific and essential, and on which we base a fourth order of drugs! For this refuge has such wide open doors that there is nothing it will not receive; there is no obscure or unknown thing which we do not foist upon its hospitality. If we allow ourselves this unlimited field for conjecture, there is not a phenomenon observed in the present connection that may not confidently be ascribed to the action of Chyna. And not merely of Chyna, but of any other spongy, rotten wood. The result is, of course, that the properties of Chyna are no longer to be weighed by reason, since this method of explanation easily allows us to say that Chyna provokes urination and perspiration, and that it draws off the peccant humours by sweat and hidden respiration, just as we know that many drugs expel some one special humour. And under cover of this sort of argument, it will not be possible for anyone to maintain that any of its powers have been falsely ascribed to Chyna by its purveyors.

. . . . . .

A detailed description of the method of preparing and administering the decoction follows, which is omitted here.—*Translator's Note.*

. . . . . .

As regards the state of mind of the patient, I would have all those who are taking Chyna be as cheerful as they possibly can in their solitude and close confinement, which is almost like a term of imprisonment, and banish from their minds all care and sadness. For I am well aware how much the cure of diseases is helped by a careless, free, relaxed state of mind as compared with a serious, excited, and preoccupied one. Those taking Guaiacum, especially if they are suffering from syphilis, are much benefited by the presence of friends and plenty of cheerful conversation on entertaining subjects. Games are also beneficial if they do not require great

mental effort and profound meditation on the result. For, of course, there are certain games, like chess (*ut est latrunculorum ille*), which exhaust the strength of the highest faculty no less than the most arduous and laborious study of some branch of learning.

. . . . . .

Some further miscellaneous precepts are here omitted.—*Translator's Note.*

. . . . . .

This is what it has occurred to me to write concerning Chyna. My observations are such as should earnestly incline us to make trial in cases of this sort rather of our native and familiar medicines, whose power is known to us, than to persuade patients to use those unfamiliar, dry, tasteless and odourless roots or stumps, which are sold very dear into the bargain.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA.*

11. *Algae from a Pan in Southern Rhodesia.*

By Florence Rich, M.A., F.L.S.

(Communicated by Miss E. L. Stephens, M.A.)

(With a sketch map and 24 figures in the Text.)

(Read July 18, 1934.)

A. Introduction.

The paper that follows is an account of the algae contained in six samples collected by Miss E. L. Stephens, of the University of Cape Town, from a large pool or "pan" at Old N'gamo in Southern Rhodesia (Tubes, Stephens, Nos. 960–965).

Old N'gamo is the site of the former N'gamo railway station, on the line between Bulawayo and the Victoria Falls (latitude about 19° S.), and it is, roughly speaking, five miles north of the present station. The line at this point runs through a "pan" from which water for the engines was formerly taken (the remains of a tank can still be seen there).

"Pan" is a South African term for a shallow depression which contains water during the rainy season, but which may dry up partially or completely during the dry season. There are a number of these Pans in the flat country between N'gamo and Old N'gamo, of which this one is the largest. Its size varies considerably with the rains: when visited in July 1927 (*i.e.* half-way through the dry season, which, in Rhodesia, is from April to September) it held a solitary pool, about a yard in diameter and four inches deep, which soon dried up completely. During 1929 the "pan" filled with water, and early in 1930 it was deep enough to cause the death of a man by drowning. On July 3, 1930, the day on which the

* From the Botanical Department, Queen Mary College, University of London.

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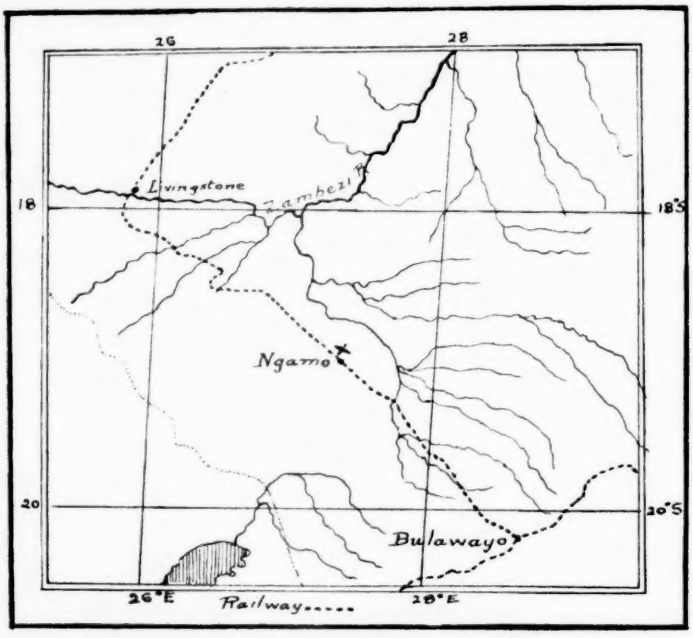
algae forming the subject of the present communication were collected, it still measured over an acre in extent, and the water in the deeper portions was over waist-deep and contained a dense tangle of aquatic and semi-aquatic vegetation. A culvert is cut through the railway-line which



Sketch map of part of Southern Rhodesia, showing the position of the site of the collection.

crosses the Pan, and through this the water slowly drains away from the deeper eastern portion where most of the collection was made. The height above sea-level is about 3000 feet.

The collection sent to me for examination includes floating filamentous algae and plankton, as well as epiphytic algae growing on *Utricularia* and *Naias*.

The temperature at Old N'gamo in July is high by day but very low at night; July and August are here the coolest months of the year.

The hydrogen-ion concentration of the water, determined by two methods, was equal to pH 7·3.

Although a considerable number of collections of algae from Equatorial and South Africa have already been investigated, none from either Northern

or Southern Rhodesia has ever, so far, been systematically examined. It is not surprising, therefore, that from this hitherto algologically unexplored region several new and interesting forms have now come under notice.*

Previously examined collections of algae have mostly been made from several places in one district or locality, or else from one pond on several different occasions; the following communication differs from all preceding ones in this series of contributions to our knowledge of the freshwater algae of Africa in that it consists of a description of the algae from one particular piece of water only, and all growing simultaneously. This is a point of ecological importance. We may feel sure that all the algae collected were living under similar conditions of temperature, acidity, concentration, and nature of dissolved salts.

As there are altogether nearly two hundred species and varieties present, the pool is evidently one of those pieces of water eminently favourable for algal growth, and may be compared to the "quiet pool in a stream" at Cedara (Natal) investigated by Fritsch and Rich in 1924, to the Weltevreden West Pan (Transvaal) investigated in 1932, and to Belfast Pan (also in the Transvaal), now under examination.

The Algae present comprise a rich growth of Chaetophorales, several representations of the Oedogoniales, and many of the Conjugatae. Diatoms are but poorly represented, there are very few Flagellates, and not many members of the Myxophyceae (Blue-green Algae).

It will be noticed that the affinities of this collection from Old N'gamo are much more with Central than with South Africa; the contents of this Pan are typically those of a small tropical lake. Allusion should here be made to Welwitsch's collection from Angola examined by W. and G. S. West in 1897. That collection extended over eight years, and comprised some marine and sub-aerial as well as freshwater algae, and is naturally much more extensive than the one now to be described. No useful comparison between the two can be made, but the richness of the Desmid flora in both deserves comment.

The present work serves to extend the known range of certain Algae, several records new for South Africa being now made; among them may be instanced *Oedogonium Boscii*, *Cosmarium bimamillatum*, *Cos. diplosporum*, *Cos. quadrifarium*, *Staurastrum botanense*, *St. floriferum*, and *St. Wildemani*.

As is frequently found to be the case in examining samples from Africa, most of the algae present differ slightly from the corresponding European forms; specially is this noticeable in the species of *Cosmarium* and *Staurastrum*, fourteen new forms or species of the former and twelve of

* The expression "South Africa" is used throughout this paper for the part of the continent south of the Kunene and Zambesi rivers (and not merely in the political sense of the Union of South Africa).

the latter being now described. The conditions obtaining in the pan at the time of collection evidently favoured sexual reproduction for about 50 species were observed to be in this state—namely, two of *Volvox*, two of *Coleochaete*, eleven of *Oedogonium*, two of *Bulbochaete*, two of *Zygnema*, three of *Spirogyra*, three of *Mougeotia*, and at least twenty-five species of Desmids. Probably spores are frequently formed in places where there is a tendency for the water to dry up, for if provision for resting stages is not made the species in such localities must inevitably die out.

It is a well-known fact that while some Desmids are often found producing zygospores, there are many widely distributed ones which rarely or never do so, possibly indicating a tendency towards the elimination altogether of zygospore formation. In view of this it is interesting to note that at Old N'gamo not only were zygospores of Desmids common, but that amongst the number were those of ten established species the zygospores of which had not previously been described—namely, *Euastrum divergens*, *Cosmarium beatum*, *Cos. lacunatum*, *Cos. Regnellii*, *Xanthidium sub-trilobum*, *Staurastrum botanense*, *St. floriferum*, *St. Manfeldtii*, *St. Tohopekaligense* var., and *St. Wildemani*.

When the first systematic observations on *Volvox* in South Africa were being made by Dr. Pocock and myself we obtained valuable material from the pan at Old N'gamo. Two species were found to be present, one the widely distributed *V. aureus*, and the other a form of the newly established *V. capensis*, a species closely allied to *V. Rousseletii*. They were associated with a *Pleodorina*.

There are very few records of the occurrence of *Bulbochaete* in South Africa. Fritsch mentions the presence of sterile forms in the Cape Province (1918) and in the Transkei Territories (1921): Hodgetts in 1925 found vegetative examples at Stellenbosch, and Borge in 1928 in East Africa. I have found sterile *Bulbochaete* in the Transvaal, as well as a little fructifying *B. varians* var. *Hawaiensis*, and have also found sterile material in Portuguese East Africa. The occurrence now of two plentifully fruiting species is therefore of interest: one of them is *B. rectangularis*, which is of wide distribution, and the other is a form closely allied to *B. varians*, also of wide occurrence.

That three species of *Mougeotia* with spores should be found here is noteworthy, as, though *Spirogyra* with ripe spores has frequently been observed in South Africa, very little fertile *Mougeotia* has hitherto been noticed.

Desmids are well represented and are characteristically tropical in type, though they include some of the ubiquitous species such as *Closterium parvulum*, *Cl. rostratum*, *Cosmarium granatum*, *Cos. punctulatum*, *Pleurotaenium Ehrenbergii*, and *Hyalotheca dissiliens*. The commonest genus is

Cosmarium, of which there are at least twenty-seven species and varieties present. There is rather an unusually large number of species and varieties of *Staurastrum*, namely eighteen, but recent collections from the Transvaal have shown that this genus is more abundant than earlier collections from other parts of Africa would seem to indicate. The abundance of Desmids tends to confirm the observation of Krieger and others that in the tropics a pH of about 7 is favourable for their development.

Though certain Diatoms are common in the Pan the class Bacillariales is not well represented, and it was not found possible to make preparations suitable for detailed examination; the genera present comprise *Asterionella*, *Eunotia*, *Gomphonema*, *Navicula*, *Hantzschia*, and *Nitzschia*, but they are not described in the following records.

It is to be regretted that there are many other algae in the collection which, in the preserved state, it was found impossible, even after prolonged examination, to determine; there are also others present in such poor numbers that characteristic features could not be made out.

The author offers her most grateful thanks to Professor F. E. Fritsch, F.R.S., of the University of London, for his kind and generous help, and to Miss E. L. Stephens, of the University of Cape Town, for supplying local information and assisting in many ways in the preparation of this paper.*

B. Systematic Enumeration of the Species Observed.†

(A reference after the specific name is given, except in the case of commonly recorded species, to figures representing the alga observed.)

CLASS I. ISOKONTAE.

Group 1. VOLVOCALES.

Genus Pandorina Bory.

Pandorina morum (Müll.) Bory.

Rather rare.

Common in South Africa.

* *Corrigenda.*—In my paper in these Transactions on Phytoplankton from South African Pans and Vleis, 1932, I designated a member of the Chroococcaceae as *Aphanothece conglomerata*; I have since realised that it is identical with *Microcystis elabens* Kütz.—F. R.

† The system of classification followed is that of West, G. S., and Fritsch, F. E., in "British Freshwater Algae," etc. (Cambridge, 1927).

Genus STEPHANOON Schewiakoff.

Stephanoon Wallichii Wille; F. Rich, 1932, Rift Valley Lakes, fig. 1, *C*.

Rather rare.

Previously recorded for Lake Naivasha.

Genus EUDORINA Ehrenberg.

Eudorina elegans Ehrenb.

Rather rare.

Common in South Africa.

Genus PLEODORINA Shaw.

Pleodorina? sphaerica Iyengar. For microphotograph see Fig. 1.

The present alga has somatic cells scattered amongst the gonidial cells and the latter are far less numerous than they are in *P. californica* Shaw, where they are said to be about equal in number to the somatic cells.

Not many colonies were seen in the material sent to England.

Genus VOLVOX (Linnaeus) Ehrenberg.

Volvox aureus Ehrenb. Described and photographed for this locality by Rich and Pocock, 1932, p. 440, Pl. xi, *B*, *C*.

The greatest size noted for asexual colonies was $782 \times 816\ \mu$, for female colonies $604 \times 625\ \mu$, and for male colonies $540 \times 560\ \mu$.

Mixed colonies were very rare, the great majority producing either gonidia alone, or antheridia alone, or oogonia alone (see Fig. 1).

Very common.

Previously recorded for South Africa.

Volvox capensis Rich and Pocock forma *rhodesiensis* Rich and Pocock, 1932, p. 447, Pl. xvi, *A–E*, and Pl. xvii, fig. *A* and *B*. (Lower part of Fig. 1.)

V. capensis is a species intermediate between *V. globator* Ehrenb. and *V. Rousseletii* G. S. West,,and was originally described from the Cape Flats. It is larger than *V. globator*, and possesses more antheridia and more oogonia; it is smaller than *V. Rousseletii*, and possesses fewer antheridia and fewer oogonia; it further differs from *V. Rousseletii* in that the male and female reproductive cells are always found in the same colony (the former in much smaller numbers than the latter). The form present in the water at Old N'gamo differs very little from the type—the oospores are a little larger and the spines on them more strongly developed; from 7 to 35 sperm globoids per coenobium were counted (from 15 to 18 being common). The number of daughter colonies in an asexual coenobium averages 8, but there is considerable variation.

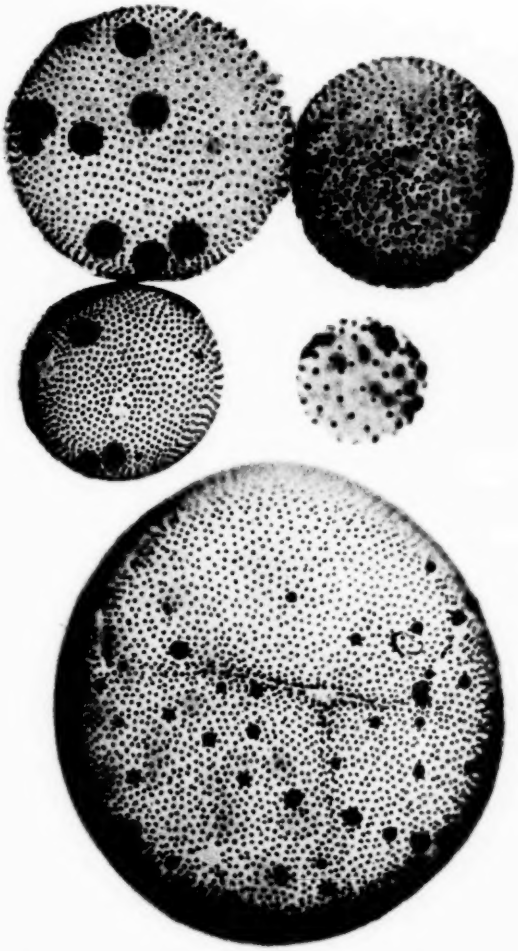


FIG. 1.—Microphotograph of *Volvox aureus* (showing two female colonies and one male colony), a colony of *Pleodorina* sp., and, below, a young sexual colony of *Volvox capensis* forma *rhodesiensis*. Photo by Dr. M. A. Pocock.

Sexual colonies measured from 600 × 624 μ to 1290 × 1335 μ; oospores, with spines, 64 to 69 μ: the number of oospores varied from 50 to 220.

Not so common as *V. aureus*.

Genus Palmodictyon Kützing.

Palmodictyon varium (Naeg.) Lemm.

Rather rare.

Not previously recorded for South Africa.

Genus Asterococcus Scherffel.

Asterococcus superbus (Cienk.) Scherffel.

See F. Rich, 1932, p. 160.

Genus Sphaerocystis Chodat.

Sphaerocystis Schroeteri Chodat.

Rather rare.

Common in South Africa.

Genus Gloeocystis Naegeli.

Gloeocystis ampla Kütz.; Pascher's Süsswasserflora, 1915, Heft 5, fig. 14, *a*.

Rather common.

Not previously recorded for South Africa.

Gloeocystis gigas (Kütz.) Lagerh.; West and Fritsch, 1927, fig. 18, *G*.

Cells 12–14 μ in diameter.

Recorded for the East African Lakes.

Genus Schizochlamys A. Braun.

Schizochlamys sp. (Fig. 2, *A*, *B*).

The alga here indicated may be a young stage of *S. hyalina* F. E. Fritsch, or it may be a stage in quite a different plant.

The cells are spherical, from 6 to 12 μ in diameter, and are usually grouped in fours in a colourless matrix. The membrane of the cell is discarded in one or two pieces. The colony depicted in Fig. 2, *B*, measured about 50 μ in diameter. The extensive soft jelly, several millimetres in width, described by Fritsch for *S. hyalina*, was not observed in the present material.

Genus GLOEOCHAETE Lagerheim.

Gloeochaete Wittrockiana Lagerh.; G. M. Smith, 1933, fig. 27.

Not uncommon.

Not previously recorded for South Africa.

GROUP 2. CHLOROCOCCALES.

Genus PEDIASTRUM Meyen.

Pediastrum tetras (Ehrenb.) Ralfs var. *apiculatum* Fritsch; 1920, p. 312, fig. 2.

Rather common.

Recorded for the Cape.

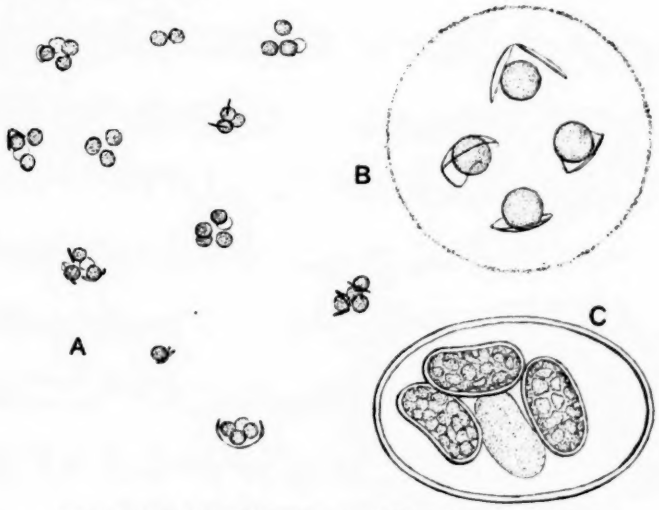


FIG. 2.—*A, B, Schizochlamys* sp. *C, Nephrocytium Agardhianum.* (*A*, × 350; *B, C*, × 750.)

Genus SORASTRUM Kützing.

Sorastrum spinulosum Naeg.; Pascher, 1915, Heft V, fig. 328.

Rather common.

Recorded for Libongo (W. and G. S. West, 1897).

Genus MICRACTINIUM Fresenius.

Micractinium radiatum Chodat.

Rare.

Recorded for Griqualand West.

Genus Oocystis Naegeli.

Oocystis solitaria Wittr.
Common.
Common in South Africa.

Genus Nephrocytium Naegeli.

Nephrocytium Agardhianum Naeg. (Fig. 2, *C*).
Kidney-shaped cells, 10–12 μ wide, 20–24 μ long.
Rather common.
Not previously recorded for Central or South Africa.

Nephrocytium lunatum W. West; 1892, fig. 39.
Cells 4 μ wide, 4 to 5 times as long.
Rather rare.
Recorded from the Transvaal.

Genus Tetraëdron Kützing.

Tetraëdron lobatum (Naeg.) Hansg. var. *sub-tetraëdricum* Reinsch; 1888, t. v, fig. 3, *e*.
Rather rare.
Not previously recorded for South Africa.

Tetraëdron minimum (A. Br.) Hansg.
Rather rare.
Of common occurrence in Africa.

Genus Ankistrodesmus Corda.

Ankistrodesmus falcatus (Corda) Ralfs.
Rather common.
Common in Africa.

Genus Kirchneriella Schmidle.

Kirchneriella lunaris (Kirchn.) Möb.
Rather common.
Previously recorded for South Africa.

Genus Dictyosphaerium Naegeli.

Dictyosphaerium Ehrenbergianum Naeg.
Rather common
Recorded for Florida Lake (Transvaal).

Genus Crucigenia Morren.

Crucigenia crucifera (Wolle) Collins; G. M. Smith, 1920, Pl. 36, fig. 6.
Rare.
Not previously recorded for Central or South Africa.

Crucigenia rectangularis (A. Br.) Gay; Pascher, 1915, Heft V, fig. 245, *a*.
Rare.
Recorded for Nyasa and L. Naivasha.

Crucigenia tetrapedia (Kirchn.) W. and G. S. West var. *apiculata* Fritsch and Rich.
Very rare.
Recorded for South Africa.

Genus Scenedesmus Meyen.

Scenedesmus bijugatus (Turp.) Kütz.
Rather common.
Common in South Africa.

Genus Coelastrum Naegeli.

Coelastrum cambricum Archer var. *intermedium* (Bohlin) G. S. West.
The spaces between the cells are either three- or four-sided.
Rather common.
Recorded from Nyasa and the Transvaal.

Group 3. ULOTRICHALES.

Genus Ulothrix Kützing.

Ulothrix subtillissima Rabenh.
Lat. cell., 5 μ; long., 18–22 μ.
Rather common.
Recorded for the Cape.

Genus Sphaeroploea Agardh.

Sphaeroploea sp.
Only a fragment of a filament was found; 9 μ wide.

Group 4. CHAETOPHORALES.

Genus Chaetophora Schrank.

Chaetophora pisiformis (Roth.) Agardh; Hazen, 1902, Pl. 38, fig. 1.
More or less spherical lumps, clinging to water plants.
Cells from 4 to 6 μ wide, up to 10 times as long.
Not uncommon.
Not previously recorded for South Africa.

Genus MICROTHAMNION Naegeli.

Microthamnion sp. Very little seen.

Genus APHANOCHAETE A. Braun.

Aphanochaeta repens A. Br.

Rather rare.

Previously recorded for South Africa.

Genus COLEOCHAETE de Bréb.

Coleochaete pulvinata A. Br. var. *minor* Pringsh. (Fig. 3).

Cells 10–13 μ broad. Oogonia from 80–100 μ in diameter. The present form seems to differ from the type in the fact that the investment of the

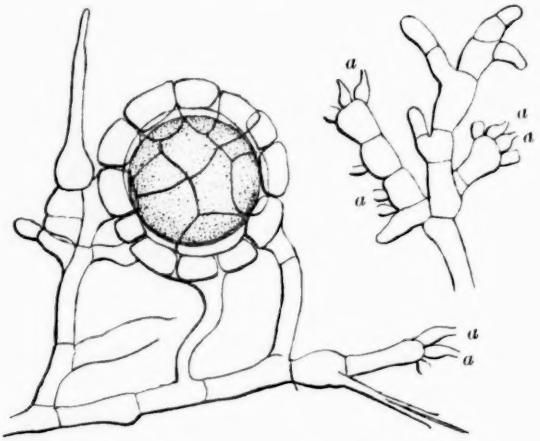


FIG. 3.—*Coleochaete pulvinata*. *a*, antheridia. (× 350.)

oospore is apparently composed of more cells (from 11 to 12 round the periphery); for this reason it is figured. Growing on *Utricularia*.

Common.

Not previously recorded for South Africa.

Coleochaete orbicularis Pringsh.

Discs more than 200 μ in diameter.

Oogonia 29 × 34 μ, or up to 42 μ.

Growing on *Naias*.

Rather common.

Previously recorded for the Cape and Transvaal.

Genus CHAETOPELTIS Berthold.

Chaetopeltis orbicularis Berthold f. *grandis* Hansg. (Fig. 4).

The cells show but slight radial arrangement, but are possessed of a thick stratified wall. Cells *circa* 20 μ broad, 20–30 μ long.

Rather common.

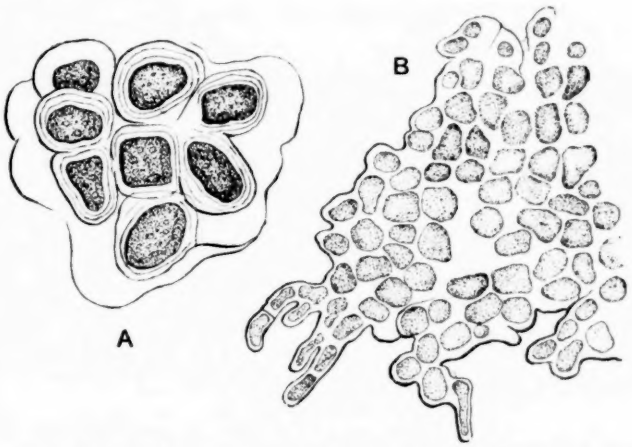


FIG. 4.—*Chaetopeltis orbicularis* f. *grandis*. *A*, a small thallus. *B*, about half of a larger thallus, not so highly magnified.

Genus CHAETOSPHERIDIUM Klebahn.

Chaetospheridium globosum (Nordst.) Klebahn.

Very common.

This is a common alga in South Africa.

GROUP 5. OEDOGONIALES.

Genus OEDOGONIUM Link.

Oedogonium acrosporum De Bary emend. Hirn *forma nov.* (Fig. 5, *C–F*).

Crass. cell. veget., 10–12 μ.

,, ,, suffult., 17–22 μ.

,, oogon., 30–32 μ; long., 38–44 μ.

,, cell. infer. stip. nannandr., 10 μ.

,, ,, antherid., 5 μ.

The longitudinal costae on the oogonium characteristic of this species are, in the present form, broken up, as shown in Fig. 5, *C*, *D*. Usually the

filament consists of a few cells only, though once as many as twenty-six cells were counted. The single terminal oogonium is characteristic, but in one instance an intercalary oogonium was observed (see Fig. 5, *E*); this is quite unusual. The slightly inflated basal cell is shown in Fig. 5, *F*.

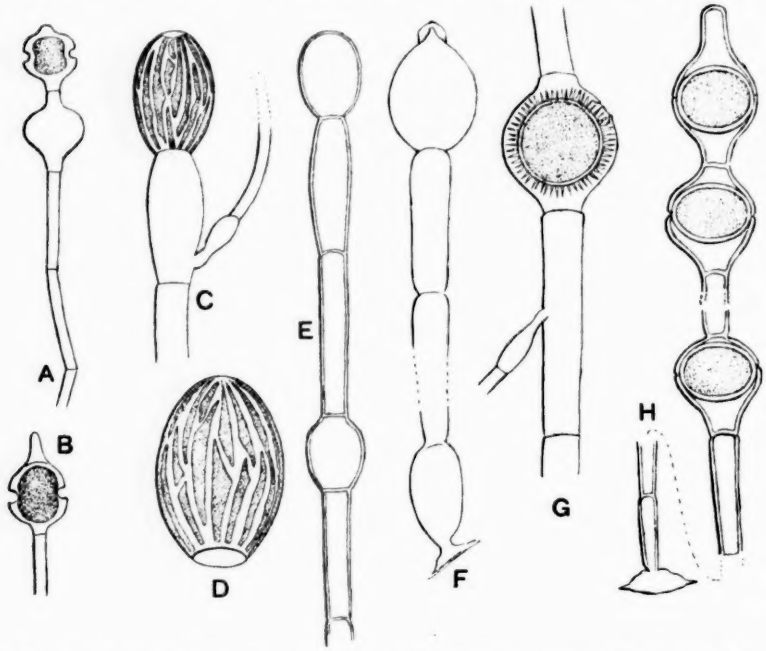


FIG. 5.—*A*, *B*, *Oedogonium pusillum*. *C*–*F*, *Oedogonium acrosporum* forma. *G*, *Oedogonium armigerum*. *H*, *Oedogonium longicolle* var. *senegalense*. (*A*, *B*, *D*, *G*, *H*, × 750; *C*, *E*, and *F*, less highly magnified.)

In dimensions the present form agrees with var. *bathmidosporum* (Nordst.) Hirn, but the dwarf male is exactly that of the type.

Rather common.

The type has been recorded for Madagascar by Fritsch (1914).

Oedogonium armigerum Hirn; 1900, Tab. XXXIII, fig. 208. (Fig. nostr. 5, *G*.)

Crass. cell. veget., 7–10 μ; 10 plo major.

,, oogon., 26–30 μ.

,, oospor. (sine spin.), 19–25 μ.

One of the smallest of the *Oedogoniums* with spiny oospores. The spines are fine and rather difficult to see. The pore is superior, and the dwarf males are sessile on the supporting cell.

The very similar macrandrous *Oe. suecicum* Wittr. was recorded for Griqualand West.

Rare.

This species not previously recorded for South Africa.

Oedogonium Bengalense Hirn.

Crass. cell. veget., 14–17 μ.

,, oogon., 55 μ.

,, oospor., 40 μ.

Vegetative cells with inflated upper ends. Dwarf males unicellular, sessile on the oogonia.

Rare.

Oedogonium Boscii (Le Cl.) Wittr.; Hirn, 1900, Tab. XIII, fig. 73.

Crass. cell. veget. plant. fem., 16 μ.

,, oogon., 41–42 μ.

,, oospor., 40 μ; long., 52–56 μ.

Agreeing perfectly with Wittrock's original figure.

Rare.

A widely distributed species but not previously recorded from South Africa.

Oedogonium cyathigerum Wittr.; Hirn, 1900, Tab. XLIII, fig. 265.

Crass. cell. veget., 27 μ.

,, ,, suffult., 40–48 μ.

,, oogon., 52–68 μ.

Long. nannandr., 50 μ.

Three or four oogonia noticed on end.

Rare.

This is not the same as the form described by Fritsch and Rich from Natal (1924), but is probably identical with the *Oe. hormosporum* W. and G. S. West described from Angola (1897).

Forma *ornatum* (Wittr.) Hirn; 1900, Tab. XLIII, fig. 267.

The dwarf males were 65 μ long.

Oedogonium longicolle Nordst. emend. Hirn; 1900, Tab. XLV, fig. 278.

Crass. cell. veget., 3–5 μ.

,, oogon., 14–15 μ.

,, fil. basal., 12 μ.

There is a gradual slight tapering from the basal to the supporting cell. The basal cell is roughly semicircular in shape.

Rather common.

Not previously recorded from South Africa.

Var. *Senegalense* Nordst. forma nov. (Fig. 5, *H*).

Crass. cell. veget., 4–6 μ.

,, oogon., 17–22 μ.

,, oospor., 16–18 μ; long., 12–13 μ.

As many as ten oogonia on end were observed.

The oospore is depressed. The basal cell is somewhat semicircular in shape, and shows a little prolongation, or horn, on each side (see Fig. 5, *H*).

Rather common.

The variety recorded from Senegal.

Oedogonium Pringsheimii Cram. var. *Nordstedtii* Wittr.; Hirn, 1900, Tab. XXVII, fig. 156.

Crass. cell. veget., 10–14 μ.

,, oogon., 30–40 μ.

,, oospor., 27–32 μ.

Oogonia single.

Rare.

The type recorded from South Africa.

Oedogonium pusillum Kirchn. (=*Oe. africanum* Lagerh., and *Oe. Klebahnii* Lemm.) (Fig. 5, *A*, *B*).

Crass. cell. veget., 2–3·5 μ.

,, oogon., 10–14 μ.

This *Oedogonium* is characterised by the possession of an oospore constricted in the middle.

Rather common.

The vegetative cells usually show a zigzag arrangement.

Recorded from Abyssinia and Cape Colony.

Oedogonium sphaerandrium Wittr. and Lund. forma Hirn: 1900, Tab. XXIV, fig. 130.

Crass. cell. veget., 6–8 μ; 5–8-plo major.

,, oogon., 24 μ.

,, oospor., 22 μ.

Cells capitate. The horizontal slit in the oogonium comes a little above the middle.

Very little seen, but it seems to come near the form described by Hirn.

This *Oedogonium* is very similar to *Oe. capitellatum* Wittr.

Rare.

Not previously recorded for South Africa.

Oedogonium undulatum (Bréb.) Al. Br.

A few short sterile filaments observed, 14 μ wide.

Recorded for the Transvaal.

Oedogonium Vaucherii (Le Cl.) Al. Br.; forma *insulare* Hirn; 1900, Tab. VI, fig. 37.

Crass. cell. veget., 23–24 μ.

,, oogon., 50 μ.

,, oospor, 40–42 μ.

Rare.

Not previously recorded for South Africa.

Other species of *Oedogonium* were present but not in a determinable condition.

Genus Bulbochaete Agardh.

Bulbochaete rectangularis Wittr. (Fig. 6, *C–E*).

This is one of those species of *Bulbochaete* in which the supporting cell

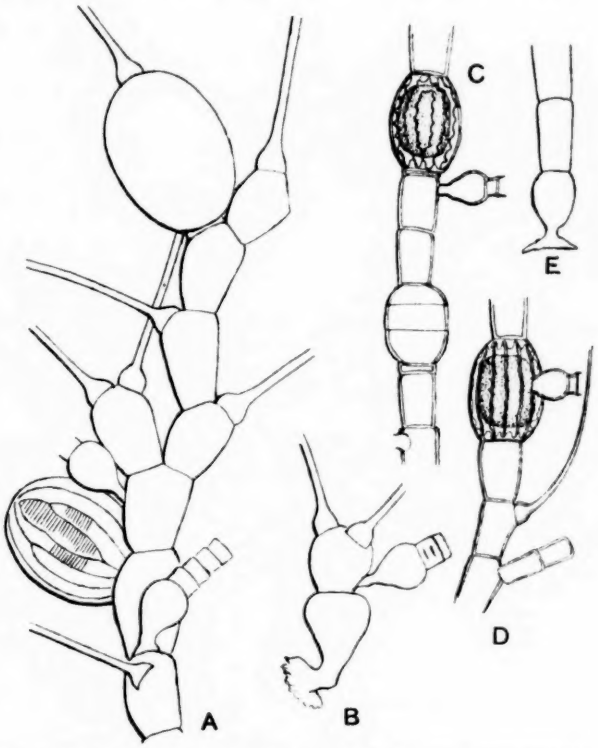


Fig. 6.—*A, B, Bulbochaete ? denticulata. C–E, Bulbochaete rectangularis.* (All × 350.)

shows a dissepiment just below the oogonium. The dwarf males were observed both on and near the oogonium.

Branching was very rare: in one case at least 18 cells on end were seen without any branching occurring. The inflated basal cell is shown in Fig. 6, *E*.

Veg. cells, 16–20 μ wide; oogonia, 32×41 μ, 30×38 μ; dwarf males (greatest width), 14–18 μ.

Rather common.

A *Bulbochaete* of wide distribution but not previously recorded for South Africa. This is not the same as the somewhat similar one I found in the Transvaal (see F. Rich, 1932, p. 165).

Bulbochaete ? denticulata Wittr. (Fig. 6, *A*, *B*).

Crass. cell. veget., 14–24 μ; $1\frac{1}{2}$–2 plo major.

,, oogon., 50–54 μ; long., 70 μ.

,, nannandr., 20–23 μ.

,, cell. antherid., 14 μ.

This *Bulbochaete* agrees with the description of *B. denticulata* (a species, however, imperfectly known), with the exception that its vegetative cells are a little smaller. Save that it fits into this in the keys given both by Hirn and by Tiffany I should be much more inclined to classify it as a variety of *B. varians* Wittr., from which species it appears to differ only in its smaller size. The antheridia are 1–4-celled; the basal cell is inflated.

Rather common.

B. denticulata is known only from Norway; *B. varians* has a much wider distribution.

Two other species of *Bulbochaete* were present, but not in a determinable condition.

Group 6. CONJUGATAE.

Series I. Eu-conjugatae.

Genus Netrium Naegeli.

Netrium digitus (Ehrenb.), Itzigs. and Rothe var. *constrictum* W. and G. S. West; Desmids I, Pl. vi, fig. 17.

Long., 200–260 μ; lat., 36–40 μ.

Scarcely narrowed in the median portion, but the sides are parallel for some distance.

Very rare.

Genus Gonatozygon De Bary.

Gonatozygon aculeatum Hastings.

Breadth at apex, 14–16 μ.

Very few individuals seen.

Recorded for the Transvaal.

Gonatozygon Brébissonii De Bary; W. and G. S. West, Desmids I, Pl. i, fig. 11.

Long., 110–150 μ; lat., ad apic., 4–6 μ.

A little smaller than the type, but not so small as var. *minutum* W. and G. S. West.

Rather rare.

Recorded for Stellenbosch.

Genus Zygnema Agardh.

Zygnema ? *hypnospora* sp. nov.? (Fig. 7, *A*).

It is difficult to know whether the *Zygnema* now under consideration belongs to one of the known species, or whether it should be placed in a

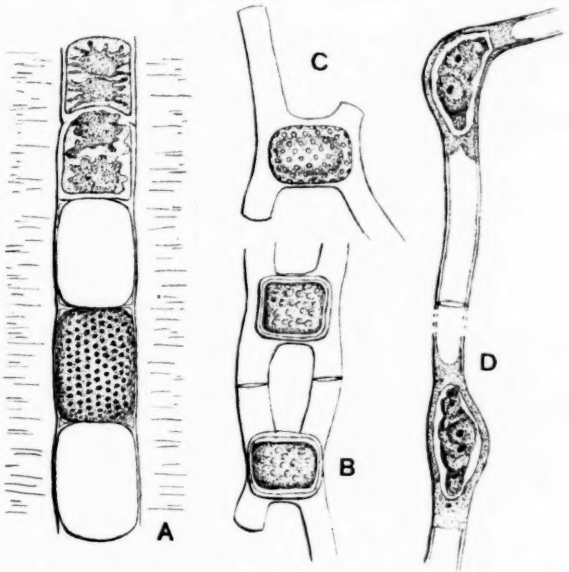


Fig. 7.—*A*, *Zygnema* ? *hypnospora*. *B*, *C*, *Mougeotia calospora* forma. *D*, *Mougeotia* sp. (*A*, *B*, *C*, × 350; *D*, × 750.)

new species, for no sexual reproduction was occurring. There was a plentiful production of hypnospores, and these were of a striking blue colour. Other *Zygnemas* are known, e.g. *Z. fertile* Fritsch and Rich (South Africa), in which the production of azygospores is frequent, or the rule, but the present species does not show close similarity to any of them.

Diam. cell. veget., 33 μ. Hypnospor., long., 34–70 μ; lat., 34 μ.

The hypnospores are cylindrical, or tumid-cylindrical in form, with flattened ends, and completely fill the containing cell. The younger spores are yellowish in colour, and the mature ones are deep greenish blue, the colour existing in the exospore. The median wall shows large scrobiculations, about ten of which are visible across the cell.

It resembles *Z. cylindrosporum* Czurda in the width of the filament, and in the shape and configuration of the spore. It seems also to bear some resemblance to *Z. cylindricum* Transeau.

Not uncommon.

Zygnema spp. Two other species of *Zygnema* were present, but not in a determinable condition.

Genus Spirogyra Link.

Spirogyra echinata Tiffany: Czurda, 1932, fig. 205.

Lat. cell. veget., 95 μ; zygospor., 73 × 73 μ.

The zygospore is brown; the mesospore furnished with numerous short spines.

Rare.

Not previously recorded for South Africa.

Spirogyra cylindrica Czurda: 1932, fig. 148.

Zygospore, 28 × 62 μ.

Very near *Sp. Spreeiana* Rabenh., but the inflated fructifying cells are cylindrical in their median portion.

Rather common.

Not previously recorded for South Africa.

Spirogyra majuscula (Kütz.) Czurda (= *Sp. orthospira* Naeg.).

Crass. cell. veget., 70–100 μ; zygospor., 60–80 μ × 68–82 μ.

Seven chromatophores, occasionally almost parallel to the cell-wall.

Rather rare.

Not previously recorded for South Africa.

Other *Spirogyras* were present but not in the reproductive stage.

Genus Mougeotia Agardh.

Mougeotia calospora (Palla) Czurda *forma* (Fig. 7, *B*, *C*).

Crass. cell. veget., 10–12 μ; zygospor., 22–24 μ × 26–30 μ.

The zygospore is broadly elliptic, or rounded rectangular in shape; it appears to differ from that of the type in the possession of rather more scrobiculations.

Rather common.

Not previously recorded for South Africa.

Mougeotia laetivirens (A. Br.) Wittr.; Czurda, 1932, fig. 63.

Crass. cell. veget., 22–30 μ.

Zygospores immature. The present form seems to be a little smaller than the type.

Rather common.

Not previously recorded for South Africa.

Mougeotia sp. (Fig. 7, *D*).

This figure represents part of the only filament seen. It was 7 μ wide, with very long cells. The spores were immature. It has been figured to show the deposit of mucilage around the spore. Cf. *M. prona* Transeau.

Series II. Desmidiaceae (Placoderm Desmids).

Genus Penium de Brébisson.

Penium minutissimum Nordst.; Krieger, 1932, Pl. vii, fig. 9, *a*.

Two zygospores were observed; the shape was somewhat rectangular, with prominent corners to which the empty semi-cells were attached, 17 × 20 μ.

Rather rare.

Recorded for Stellenbosch.

Genus Closterium Nitzsch.

Closterium Dianae Ehrenb. var. *arcuatum* (Bréb.) Rabenh.

Rather rare.

(Another variety was found in the Transvaal.)

Closterium gracile Bréb.; W. and G. S. West, Desmids I, Pl. xxi, figs. 8, 9, 12.

Length, 150–170 μ; width, 5–6 μ; diam. of zygospore, 20 μ.

The zygospore was sub-quadrate with rounded angles.

Rare.

Recorded for the Knysna Forest and the Transvaal.

Closterium Kützingii Bréb.

Rare.

Recorded for the East African Lakes.

Closterium moniliferum (Bory) Ehrenb.

Dist. inter apic., 214 μ; lat., 32 μ.

The apices of the semi-cells are obtusely rounded; the curvature here is greater than is usual for *Cl. moniliferum*, and more closely resembles that of the allied species *Cl. Leibleinii* Kütz.

Very rare.

Recorded for South Africa.

Closterium parvulum Naeg. var. *angustum* W. and G. S. West (Fig. 8, *A*).

Dist. inter apic., 70–92 μ; lat., 7–10 μ; zygospor., 22×26 μ. The individuals measured were rather short. One zygospore was noticed, ellipsoid in shape, a little smaller than that of the type.

Rather common.

Recorded for Lake Naivasha.

Closterium porrectum Nordst. var. *angustatum* W. and G. S. West.

Dist. inter apic., 200 μ; lat., 17 μ.

Rare.

Not previously recorded for South Africa.

Closterium setaceum Ehrenb.

Long., 320 μ; lat., 13 μ.

Rare.

Recorded for Portuguese East Africa.

Closterium Venus Kütz.

Rather rare.

Recorded for South Africa.

Genus Pleurotaenium Naegeli.

Pleurotaenium Ehrenbergii (Bréb.) De Bary *forma*.

Width across swelling, 15 μ; width at apex, 12 μ; length, 380 μ.

This is narrower than any hitherto described form, but agrees in proportion, and other respects, with the type.

Rather rare.

Previously recorded for South Africa.

Pleurotaenium sub-coronulatum (Turner) W. and G. S. West (Fig. 8, *B*).

Long., 240–500 μ; lat. ad bas. semi-cell., 28–32 μ.

The semi-cells showed a prominent apical as well as a basal inflation, and the sides were obscurely undulate. The apices were crowned with a ring of leaf-like tubercles, below which the cell-wall was slightly fluted. Some of the individuals found resembled those described for Natal (1924) but, as a rule, the apical swelling was more pronounced.

Rather common.

Previously recorded for Natal.

Forma nov. *major*.

A few semi-cells were observed which were distinctly wider than any forms previously described, the width across the basal swelling measuring 55 μ. The wall of the cell was punctate, and the crown of tubercles was just like that of the type.

Var. *detum* W. and G. S. West; 1896, figs. 2, 3. (Fig. nostr. 8, *C*.)

Long., 460–660 μ; lat. ad bas. semi-cell., 38–45 μ.

The chief characteristic of var. *detum* lies in the possession of a sub-apical constriction, the distance of which from the apex is about one-sixth of the length of the semi-cell. Fritsch and Rich (1924) found in Natal all transitions between this and normal individuals, and in consequence expressed a doubt as to whether the variety could be maintained; but as

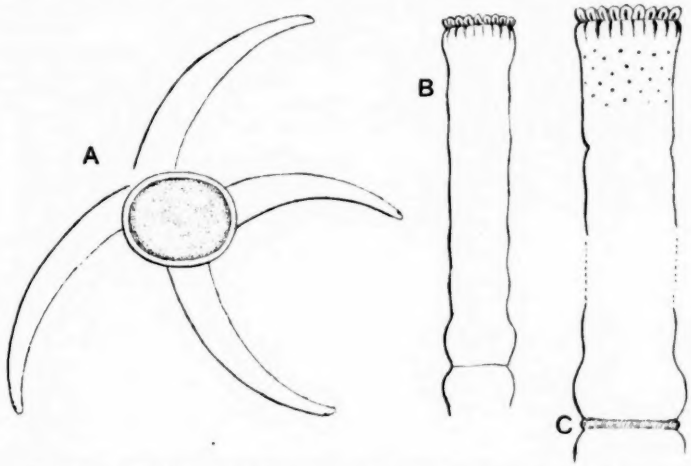


FIG. 8.—*A*, *Closterium parvulum* var. *angustum* zygospore. *B*, *Pleurotaenium sub-coronulatum*. *C*, *Pl. sub-coronulatum* var. *detum*. (*A*, × 750; *B*, *C*, × 350.)

in the collection now under examination the majority of the individuals observed possessed this constriction and were regularly about 40 μ wide across the basal swelling, I feel now that this is a distinct variety.

It was noted in the Natal collection that many individuals were found cohering by their apices: in one of the present samples twenty-four semi-cells were observed thus cohering (each about 280 μ long).

Genus EUASTRUM Ehrenberg.

Euastrum binale (Turp.) Ehrenb.; W. and G. S. West, Desmids II, Pl. xxxviii, fig. 29.

Very rare.

Forma *secta* Turn.; W. and G. S. West, Desmids II, Pl. xxxviii, fig. 30.

Long., 20 μ; lat., 16 μ.

Rare.

This species has been recorded for South Africa.

Euastrum divergens Joshua var. nov. *Rhodesiense* (Fig. 9, *A–C*).

Var. lobis lateralibus inferioribus semicellularum in aspectu frontali vix prominentibus ut in var. *bifidum* Schmidle, sed lobo polari haud lateraliter explanato; pyrenoidibus duabus in quaque semicellula.

Long. cell., 42–45 μ; lat. cell., 46–60 μ; isthm., 10 μ; crass., 20–23 μ; lat. zygospor. (sine spin.) 27–40 μ; long. spin., 10–14 μ.

This variety differs from the type mainly in the form of the lower

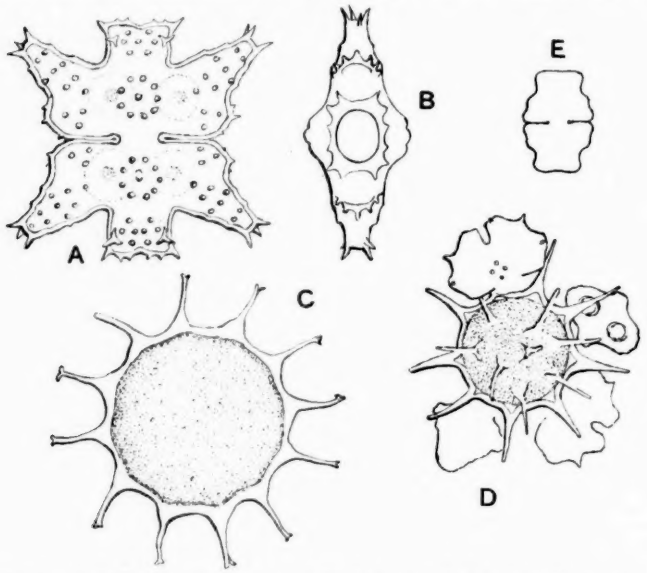


FIG. 9.—*A–C*, *Euastrum divergens* var. *Rhodesiense*. *D*, *Euastrum elegans* var. *madagascariense*, zygospore. *E*, *Euastrum insulare* forma. (All × 750.)

lateral lobes (see Fig. 9, *A*). In the two original figures given by Joshua in 1885 a certain variability in these lobes is already noticeable; here these lobes scarcely protrude at all, resembling in this respect var. *bifidum* Schmidle (but differing in the shape of the polar lobe). The polar lobe is 12–14 μ wide. The central tumour is furnished with a granule (which may be single or double) surrounded by a circle of from 8 to 10 other granules.

The zygospore of *Euastrum divergens* has not hitherto been described. Several zygospores of the new variety were found in the present collection; they are spherical, and are furnished with rather long slender spines which rise from a swollen base, and fork at the tip.

Rather common.

This *Euastrum* belongs to a group comprising *Eu. breviceps, bellum, spinulosum, spicatum, sphyroides, substellatum, commisurale, Hieronymusii, hypochondroides, hypochondrum, monocyclum, platycerum, quadratum,* and *verrucosum* (nearly all of which are non-British).

Eu. divergens was first described from Burmah, in 1885, and has not since been recorded.

Euastrum elegans (Bréb.) Kütz., var. *madagascariense* W. and G. S. West, *forma* as in the Transvaal; Rich, 1932, fig. 6, *C*. (Fig. 9, *D*.)

Long. cell., 28 μ; lat., 20–22 μ; crass., 11–13 μ; lat. zygosp. (sine sp.), 20–26 μ; long. spin., *circa* 8–12 μ.

The zygospore is similar to that of the type, but the spines, when fully ripe, are longer.

Rather rare.

The type has been recorded from Natal.

Euastrum insulare Roy *forma* (Fig. 9, *E*).

Long. cell., 20 μ; lat. cell., 14–15 μ.

The lateral lobes are not so rectangular as in the type; very similar to a form from Cambridgeshire described by G. S. West.

Rare.

Recorded for Lake Naivasha.

Euastrum Turneri West *forma* G. S. West., 1914, fig. 39.

Long. cell., 33–40 μ; lat. cell., 25–26 μ; isthm., 4 μ.

Rare.

Formae recorded from the Knysna Forest by Huber.-Pestalozzi.

Genus Micrasterias Agardh.

Micrasterias crux-melitensis (Ehrenb.) Hass.; Desmids II, Pl. liii, fig. 1.

Rather rare.

Recorded from the Transvaal.

Var. *evoluta* W. B. Turner.

A little smaller than the forms found in the Transvaal, 1932.

Rather rare.

Micrasterias Mahabuleshwarensis Hobson *forma* Raciborski, 1895.

Very few individuals seen. It appeared to agree with the form from British Guiana described by Raciborski, although it was a little smaller.

Long. cell., 100 μ; lat., 92 μ; isthm., 20 μ.

The type recorded from the Transvaal and Portuguese East Africa.

Genus Cosmarium Corda.

Cosmarium asymmetricum sp. nov. (Fig. 10, *D–H*).

Cosmarium pusillum, fere tam longum quam latum, profunde constrictum, sinu clauso. Semicellulis in aspectu frontali asymmetricis, subrectangularibus, apicibus latis deplanatis, lateribus retusis, angulis superioribus in uno latere plus prominentibus quam in altero; semicellulis

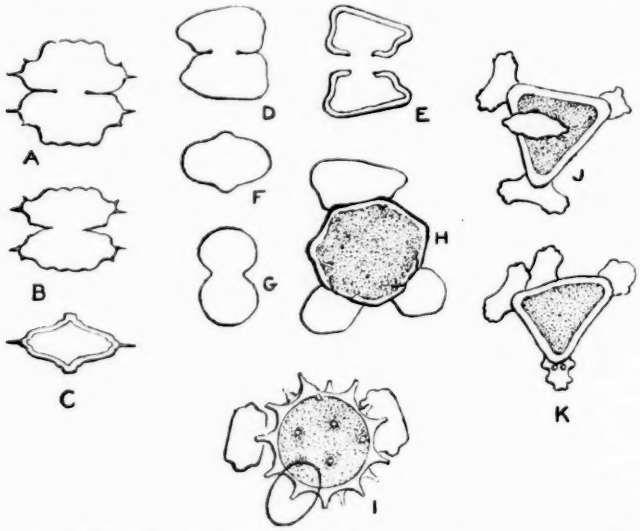


Fig. 10.—*A–C, Cosmarium sub-humile. D–H, Cosmarium asymmetricum*; *H*, zygospore. *I*, zygospore of *Cosmarium Regnellii* forma *minor*. *J*, *K*, zygospore of *Cosmarium Regnesi* var. *montanum*. (All the same magnification.)

in aspectu laterali subcircularibus. Zygosporis irregulariter polyhedricis, exospora in angulis leviter incrassata.

Long., 13–14 μ; lat., 10–14 μ; isthm., 3–4 μ; crass., 8–10 μ; zygospores 13×15, 17×18, 16×20 μ.

This is a small *Cosmarium* characterised by its asymmetric shape. I cannot find a description of any other in which one-half of the semi-cell is not a reflection of the other. The end-view shows a central protuberance on both sides. The side-view of the semi-cell is subcircular (not quite symmetrical). The zygospore is irregularly polyhedral, and the exospore is slightly thickened at the angles; a perfectly ripe one was not observed.

This *Cosmarium* approaches some forms of *C. Regnellii* Wille, but does not resemble them sufficiently to warrant inclusion in this species.

Not uncommon.

Cosmarium beatum W. and G. S. West *forma* (Fig. 11, *A*).

Long. cell., 26–30 μ; lat., 23–27 μ; isthm., 8–10 μ; crass., 17–21 μ; zygosp. sine sp. 29 μ, cum sp. 42 μ.

There is a very close agreement between the individuals now found and those of *C. beatum*, originally described by the Wests from Madagascar (1895). The main difference observable is that in end-view the lateral protuberance is bi- and not tri-undulate (markings on the surface were not distinguished). The length is slightly less than that given by the Wests, but their measurements may have been taken from an individual preparing

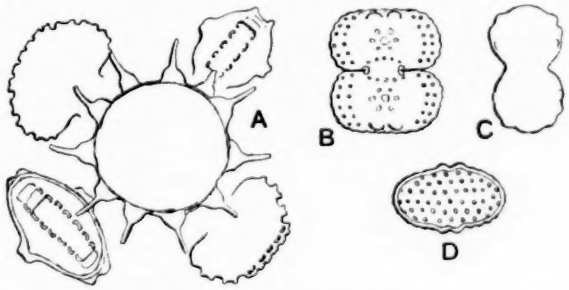


FIG. 11.—*A*, zygospore of *Cosmarium beatum*. *B–D*, *Cosmarium bimamillatum*. (All × 750.)

to divide (see their figure, Pl. vii, 8, *a*). The zygospore is spherical and furnished with rather long spines, which rise from a swollen base (see Fig. 11, *A*). Zygospores of *C. beatum* have not previously been described.

Common in the samples.

The type recorded for Madagascar and for East Africa.

Cosmarium bimamillatum Krieger; 1932, Pl. xiii, fig. 3; forma nov. *minor* (Fig. 11, *B–D*).

Long. cell., 22–25 μ; lat., 20–23 μ; isthm., 5–6 μ; crass., 12–14 μ (? zygosp. sine proc. 24 μ, cum proc. 40 μ).

The outline of the cell-wall is undulate, and there are two tubercles just below the apex on both sides. The surface is rather coarsely punctate; the punctae are arranged in eight or nine vertical rows and five or six horizontal rows. The end-view is broadly elliptic, with two tubercles on both sides. The side-view of the semi-cell is subcircular, with the tubercles appearing near the apex. There is one pyrenoid in each semi-cell.

(One zygospore was observed.)

The form now found differs from the type (which has been recorded only from Sumatra) in its smaller size; the proportions and other features

are the same. It somewhat resembles *C. mamilliferum* (see Fig. 13, *G*) in its end- and side-views, but the shape of the cell in front-view is different, and the margin here is not entire.

Rather rare.

Not previously recorded for Africa.

? *Cosmarium bireme* Nordst. forma.

Long. cell., 6 μ; lat., 6–7 μ.

An extremely small form. Var. *barbadense* West is about the same size, but not the same shape.

This is a doubtful determination, as the end-view was not observed.

Rare.

The type has been recorded from Equatorial Africa.

Cosmarium Blyttii Wille.

Long. cell., 13–17 μ; lat., 14–16 μ; isthm., 4 μ; crass., 6–9 μ.

Widely distributed in South and Central Africa.

Formae. So many forms of *C. Blytii* are present in these samples that it is not easy to separate them. A form similar to *bipunctatum* Dick occurs, but it is smaller, the width being only 16 μ, whereas Dick's *forma* measured 20 μ.

var. *Novae Sylvae* W. and G. S. West.

Long. cell., 18 μ; lat., 18 μ; isthm., 4·5 μ; crass., 9–10 μ.

A variety marked by its more prominent lateral crenations, and the presence of four small granules in front-view.

Rather common.

Not previously recorded for South Africa.

Cosmarium connatum Bréb.; W. and G. S. West, Desmids III, Pl. lxvii, fig. 16.

Long. cell., 60–74 μ; lat., 43 μ +; isthm., 31 μ; crass., 36 μ.

Very rare.

Not previously recorded for South Africa.

Cosmarium diplosporum (Lund.) Lütkem. (= *Cylindrocystis diplospora* Lund.); Homfeld, 1929, Pl. v, fig. 57.

Long. cell., 70 μ; lat., 29 μ; zygospor., 42–43 μ.

The half-zygospores do not possess the sub-rectangular shape said to be characteristic of this Desmid, but approach a more spherical form, hereby resembling those described by Homfeld from North-West Germany.

Quite common among the masses of *Coleochaete pulvinata*.

Not previously recorded for South Africa.

Cosmarium formosulum Hoff.

Long. cell., 40–44 μ; lat., 34–36 μ; isthm., 10–11 μ; crass., 19–22 μ.

Numerous individuals were measured, and the narrow range of size should be noted. The apex was usually 4-crenate, but an occasional 6-crenate form was observed.

Rather common.

Recorded for the Cape.

Cosmarium granatum Bréb.

Long. cell., 30 μ; lat., 20 μ; isthm., 6 μ.

Rare.

Widely distributed in South Africa.

Cosmarium humile (Gay) Nordst.: Wests' Desmids III, Pl. lxxxv, fig. 18.

Surface markings not observed. Very few individuals seen.

Recorded for the Transvaal.

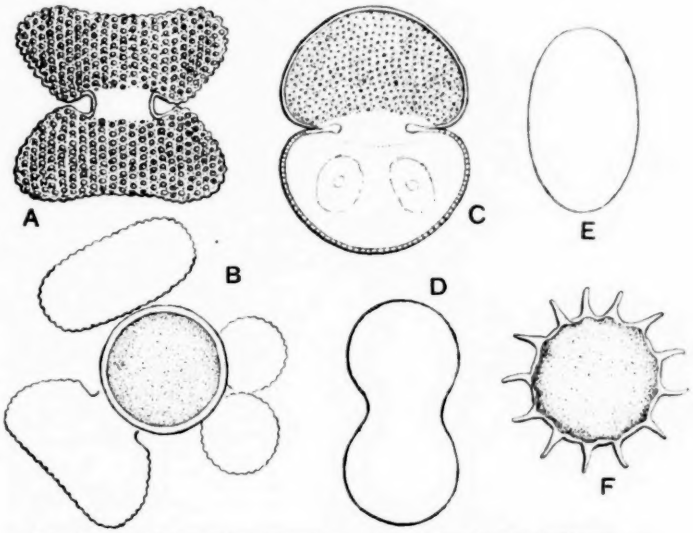


Fig. 12.—*A*, *B*, *Cosmarium lacunatum*. *C–E*, *Cosmarium pachydermum* var. *aethiopicum*. *F*, zygospore of forma *minor*. (All × 350.)

Cosmarium lacunatum G. S. West *forma nov.* (Fig. 12, *A*, *B*).

Long. cell., 80–84 μ; lat. apic. semi-cell., 79–90 μ; isthm., 20–25 μ; crass., 30 μ; zygospore, 46 × 54 μ.

There are eight or nine horizontal rows of granules, and about twenty vertical rows; from 36 to 40 granules are discernible round the margin of the semi-cell.

C. lacunatum was first discovered during the third Tanganyika Expedition. It is distinguished by the upwardly divergent sides of its semi-cells and its much dilated sinus. In the present collection the individuals observed, while possessing the divergent sides, do not always show a much dilated sinus, and the apex of the semi-cell is slightly retuse. They somewhat resemble *C. quadrum* Lund. var. *sublatum* (Nordst.) W. and G. S. West,* and show precisely similar markings, viz. large granules each surrounded by six small punctae. In *C. lacunatum*, however, there are said to be punctulations between the granules, though these are not figured by G. S. West, 1907, Pl. vii, fig. 9.

The present *Cosmarium* resembles *C. porrectum* Nordst. in its shape, but the sinus of the latter is longer and narrower.

In one of the samples a zygospore was observed; it was sub-spherical in form, with a smooth wall (Fig. 12, *B*). Zygospores have not hitherto been recorded for either of the *Cosmaria* alluded to above.

Rather common.

Cosmarium mamilliferum Nordst. var. *madagascariense* W. and G. S. West *forma nov.* (Fig. 13, *F–J*).

Long. cell., 29–30 μ; lat., 24–27 μ; isthm., 6–8 μ; crass., 12–15 μ.

The tubercles in the present form are larger than in the type, and there are three smaller tubercles just below them. The surface is more coarsely punctate than in the variety described by W. and G. S. West from Madagascar (1895, p. 57).

One specimen observed (see Fig. 13, *J*) was distinctly stipitate, the stalk of attachment having its origin between the two tubercles on one side of a semi-cell. A stalked individual of *C. polygonum* var. *exile* W. and G. S. West, from West Africa, is described and figured by the Wests in Desmids III, p. 76 and Pl. xci, fig. 13.

Not uncommon.

Recorded for Madagascar and Victoria Nyanza.

Cosmarium moniliforme Ralfs.

Some individuals resembled var. *sub-truncatum* Lemm. in shape.

Rather common.

Recorded for Central Africa.

Cosmarium pachydermum Lund. var. *aethiopicum* W. and G. S. West. (Fig. 12, *C–F*.)

Long. cell., 100 μ; lat., 70–80 μ; isthm., 28–30 μ.

* A form placed by the present writer in 1932 under *C. quadrum* var. *sublatum* is probably the same as that now under consideration (see Trans. Roy. Soc. S. Africa, vol. xx, fig. 8, *D*).

The wall of this variety is not so thick as that of the type. There are numerous minute punctulations scattered between the larger ones, as shown in Fig. 12, *C*, and described by W. and G. S. West, Desmids II, p. 141.

Common.

Recorded from West Africa.

A large form of this variety was recorded from Natal.

Forma nov. *minor*.

Not all the individuals present were as large as the above, the majority of them being a little smaller, but differing in no other respect.

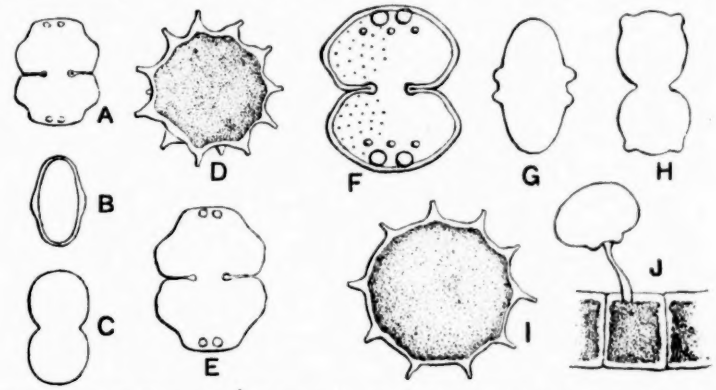


FIG. 13.—*A–D, Cosmarium sub-hammeri. E, Ibid.*, forma *major*. *F–J, Cosmarium mamilliferum* var. *madagascariense* forma. *J*, unusual stalked individual growing on a filament of *Zygnema*. (All × 750.)

Long. cell., 66–82 μ; lat., 54–60 μ; isthm., 20–26 μ; crass., 34–40 μ; zygosp. sine sp. 50 μ, cum sp. *circa* 74 μ.

A few zygospores were observed (see Fig. 12, *F*); they were similar to those of *C. pachydermum* described by Homfeld (1929, p. 48).

Rather common.

Cosmarium Phaseolus Bréb. var. *elevatum* Nordst. forma nov. *minor*; W. and G. S. West, Desmids II, Pl. lx, figs. 16, 17.

Long. cell., 20–21 μ; lat., 18–20 μ; isthm., 4–6 μ.

Cell-wall punctate; a protuberance on each side in the vertical view.

Rare.

Recorded for Equatorial Africa.

Cosmarium polygonum (Naeg.) Arch. var. *minus* Hieron.

Long. cell., 10–11 μ; lat., 9–10 μ.

Rather rare.

Another variety, but not this one, was recorded from Griqualand West.

Cosmarium Portianum Arch.: W. and G. S. West, Desmids III, Pl. lxxx, fig. 5, and Allorge, 1930, Pl. x, fig. 35.

Long. cell., 22–28 μ; lat., 20 μ; isthm., 7–8 μ; crass., 14 μ; zygosp. (sine sp.), 24 μ.

The Wests remark that the tropical forms of this species are smaller than those occurring in temperate regions; this is borne out by the above measurements. One zygospore was observed furnished with short blunt spines measuring about 4 μ in length.

Common.

Recorded from Equatorial Africa.

Cosmarium pseudo-sulcatum sp. nov. (Fig. 14).

Cosmarium mediocre, ca. 1¼ plo long. quam lat., profunde constrictum, sinu lineari aperto; semicellulis in aspectu frontali late hexagonis, apicibus

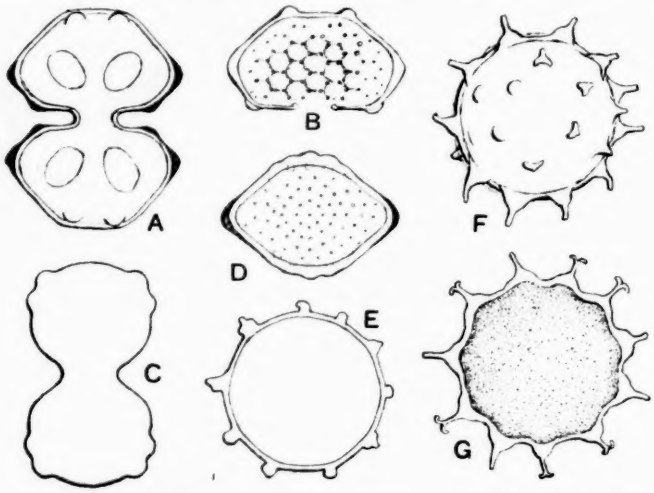


FIG. 14.—*Cosmarium pseudo-sulcatum*. *E–G*, zygospores in various stages of development. (All × 750.)

deplanatis, angulis basalibus et lateralibus rotundatis saepe incrassatis, infra apicem plerumque cum tuberculis duobus in utroque latere, in superficie cum inflationibus pumilis in 4–5 seriebus horizontalibus ordinatis punctis 6 circumdatis et interdum vix conspicuis; semicellulis in aspectu laterali subrotundis, a vertice visis ellipticis inflationibus pumilis paucis in utroque latere; pyrenoidibus duabus in quaque semicellula. Zygosporis rotundis, spinis brevibus basin versus dilatatis obtectis.

Long. cell., 42–48 μ; lat., 34–39 μ; isthm., 7–9 μ; crass., 24–26 μ; zygospor. (sine spin.), 34–42 μ; long. spin., ad 10 μ.

The broadly hexagonal semi-cells are usually furnished with two rounded tubercles below the apex on both faces, and other less pronounced swellings appear below them. These tubercles are evidently a variable feature, sometimes occurring at the lower angles of the semi-cell (see Fig. 14, *A*, *B*), but sometimes being absent from this position. The surface is covered with minute punctae, six of which are visible round each incipient swelling. The lateral angles are usually thickened. The sinus is often widely open, in which respect, and in many others, this *Cosmarium* resembles *C. sulcatum* Nordst. var. *africanum* Borge, but it differs in the possession of tubercles. In end- and side-views it shows a resemblance to *C. bicorne* Borge, but the front-view is not the same. The zygospore is round and is covered at first with rounded papillae which lengthen out to form short spines (finally bifurcate or ? trifurcate) on swollen bases.

Common.

Cosmarium punctulatum Bréb. var. *seriatum* Krieger: 1932, Tab. XII, fig. 11.

Long. cell., 20–23 μ; lat., 20 μ; isthm., 5 μ; crass., 10–12 μ.

Rather rare.

The type is almost universally distributed.

Cosmarium pygmaeum Arch.

Long., 12–13 μ; lat., 10–12 μ; isthm., 4–5 μ; crass., 6 μ; zygospor., 16 μ.

Rather rare.

Recorded from the Transvaal.

Cosmarium quadrifarium Lund. *forma.*

Long., 49 μ; lat., 30–33 μ; isthm., 10 μ.

Undoubtedly a form of this species, but not enough individuals were seen to render a good description possible.

Rare.

Not previously recorded from South Africa.

Cosmarium Regnellii Wille; W. and G. S. West, Desmids III, Pl. lxxii, fig. 25.

Long. cell., 18–20 μ; lat., 14–18 μ; isthm., 4 μ; diam. zygosp. (sine sp.), 14–15 μ.

One zygospore was observed but not very distinctly; it was spherical and furnished with small narrow spines. The zygospore has not previously been described.

Rather common.

Recorded from South Africa.

Forma *minor* Boldt. (Fig. 10, *I*).

Long. cell., 11 μ; lat., 10 μ; zygosp. (sine sp.), 14–15 μ; cum sp., *circa* 20 μ.

Rather rare.

One zygospore was observed; the spines in this case were blunt (see Fig. 10, *I*).

Cosmarium Regnesi Reinsch var. *montanum* Schmidle (Fig. 10, *J*, *K*).

Long. cell., 10–12 μ; lat., 9–13 μ; isthm., 4–6 μ; crass., 6 μ; zygosp., 12–14 μ.

The zygospores of this variety have not previously been described; they are not very different from those of the type; they appear to be tetrahedral (see Fig. 10, *J*, *K*), and the empty semi-cells are attached to the angles; the sides are convex, or slightly concave.

Rather common.

Recorded from Madagascar and Tanganyika.

Cosmarium sexangulare Lund. forma *minima* Nordst.

Rare.

Recorded for South and Equatorial Africa.

Cosmarium sub-hammeri sp. nov. (Fig. 13, *A–D*).

Cosmarium parvum, ca. 1¼ plo long. quam lat., subhexagonum, profunde constrictum, sinu anguste lineari apice leviter dilatata; semicellulis in aspectu frontali truncato-pyramidatis, marginibus lateralibus inferioribus leviter sursum divergentibus, marginibus superioribus retusis, angulis superioribus rotundatis, apicibus rectis vel leviter convexis, papillis duabis infra apicem in utroque latere; a latere visis semicellulis subrotundis, a vertice ellipticis inflatione parva in utroque latere. Membrana glabra, pyrenoide singula in quaque semicellula. Zygosporis rotundis, spinis brevibus basin versus inflatis praeditis.

Long. cell., 20–22 μ; lat., 16–18 μ; isthm., 4–6 μ; crass., 11–13 μ; zygosp. (sine sp.), 20–24 μ; cum sp., 26–32 μ.

The lower part of the semi-cell is often faintly tri-undulate. There are two papillae just below the broad truncate apex on each face. The presence of papillae distinguishes this species from *C. trilobulatum* Reinsch and *C. hammeri* Reinsch, both of which in form it closely resembles. From *C. trilobulatum* it is further distinguished by the slight lateral enlargement visible in end-view (see Fig. 13, *B*). The zygospore is spherical, and is furnished with short spines on swollen bases (Fig. 13, *D*).

Very common.

Forma *major* (Fig. 13, *E*).

Long. cell., 27–32 μ; lat., 21–24 μ; isthm., 6 μ; crass., 12–14 μ; zygosp. (sine sp.), 26 μ; cum sp., 33–36 μ.

In general appearance this form very closely resembles *C. hammeri* var. *africanum* Fritsch (1920, fig. 11, *B*, p. 333). It has, however, upwardly divergent lower margins to the semi-cells and possesses two apical papillae on both sides.

The zygospore is similar to that of the type.

Rather common.

Cosmarium sub-humile sp. nov. (Fig. 10, *A–C*).

Cosmarium parvum, ca. tam longum quam latum, profunde constrictum, sinu clauso; semicellulis in aspectu frontali trapeziformibus, basin versus latioribus quam in apice, apicibus truncatis 4-undulatis, lateribus protractis spinis parvis duabus praeditis; a vertice visis semicellulis ellipticis, inflatione distincta in utroque latere et spina parva in utroque fine.

Long. cell., 10–13 μ; lat., 11–14 μ; isthm., 3–4 μ; crass., 8 μ.

This small *Cosmarium* bears a slight resemblance to *C. humile* (Gay) Nordst. with its 4-undulate apex and flattened semi-cells. It is distinguished, however, by the protraction of its lateral angles to form spines and by its rather elaborate end-view with short terminal spines.

Of common occurrence.

Genus Xanthidium Ehrenberg.

Xanthidium concinnum Arch. *forma* F. Rich, 1932.

Long. cell., 9 μ; lat., 10 μ; isthm., 2 μ.

A form with rather long lateral spines, similar to that found in Weltevreden West Pan (Transvaal).

Very rare.

Xanthidium subtrilobum W. and G. S. West *forma* Krieger, 1932. (Fig. 15, *A*.)

Long. cell. (sine sp.), 70 μ; lat. (sine sp.), 70 μ; isthm., 14 μ.

Though larger than the form described by Krieger from Sumatra it resembles it very closely in shape. It is not so markedly tri-lobed as the type described by W. and G. S. West from Equatorial Africa. Not many individuals were found, and punctulations on the surface were not noticed.

Forma nov. (Fig. 15, *B–D*).

Long. cell., 66–70 μ; lat., 65–70 μ; long. spin., *ca.* 15 μ; isthm., 14–17 μ; crass., 36–44 μ; zygosp. (sine sp.), 60–66 μ; cum sp., 106–120 μ.

A form which differs from the above in possessing a few rather coarse denticulations along the lower lateral margin, and a more angular sinus. There is also a single granule below the circle of (9–11) granules observable on the face of the semi-cells. The lower spines may be single or double.

Of this form a few zygospores were observed (see Fig. 15, *D*). They were spherical and furnished with long slender spines from 23 to 27 μ in length.

The zygospores of *X. subtrilobum* have not previously been described.

Xanthidium sp. nov. (?) (Fig. 15, *E*).

Long. cell. (sine sp.), 75 μ; lat. (sine sp.), 74 μ; isthm., 20 μ.

The individual figured is the only one found. The semi-cells are by no means three-lobed, and it could not be considered to belong to *X. subtrilobum* were it not that it is linked to this species by the form shown in Fig. 15, *B*, with the denticulate lower lateral margin.

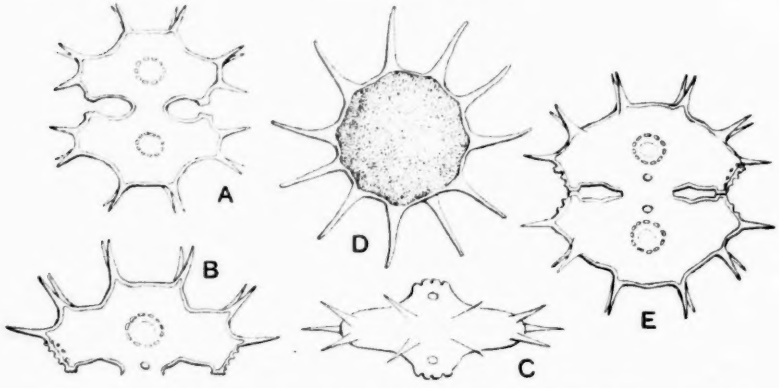


FIG. 15.—*A*, *Xanthidium subtrilobum* forma Krieger, 1932. *B–D*, *Xanthidium subtrilobum* forma nov. *E*, *Xanthidium* sp. nov.? (All × 300.)

Genus ARTHRODESMUS Ehrenberg.

Arthrodesmus Incus (Bréb.) Hass. var. *validus* W. and G. S. West *forma nov.* (Fig. 16, *A*).

Long. sine sp., 36–40 μ; lat. sine sp., 38–44 μ; isthm., 8–9 μ; long. sp., 21–22 μ.

This *Arthrodesmus* differs from var. *validus* in being a little wider and a little longer, and in possessing shorter spines (those of the variety measuring 27 to 42 μ). The spines were solid in the individuals observed.

Rather rare.

The type recorded from the Cape.

Arthrodesmus subulatus Kütz., forma nov. *triquetra* (Fig. 16, *B–D*).

Long. cell., 25–32 μ; lat. cum aculeat., 42–54 μ; isthm., 8–11 μ; zygosp., 32–36 μ.

Cells deeply constricted, sinus widely open from a more or less subacuminate apex; semi-cells ob-semicircular, ventral margin much more convex than the dorsal margin, lateral angles furnished with a fairly long, stout, straight spine (5–9 μ long), almost horizontally disposed, only slightly

incurved. Vertical view triangular, the sides slightly concave. Cell-wall finely punctate. Zygospore globose, with a smooth thick wall.

This affords another example of the transitional forms which link the genera *Arthrodesmus* and *Staurastrum*.

It resembles some forms of *St. megacanthum* Lund., especially that

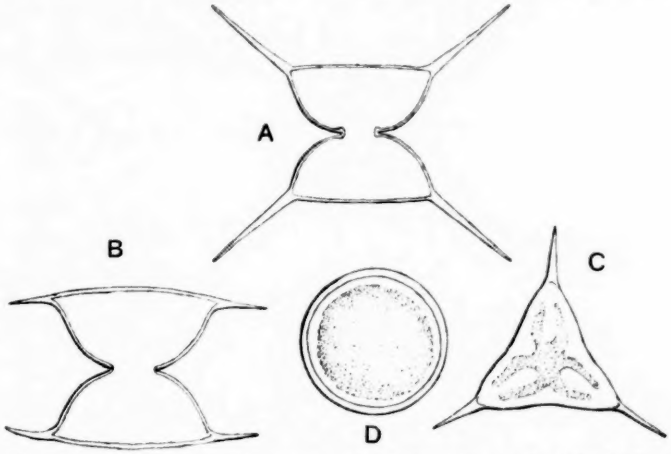


FIG. 16.—*A*, *Arthrodesmus Incus* var. *validus* forma nov. *B–D*, *Arthrodesmus subulatus* forma *triquetra*. *D*, zygospore. (*A*, × 600; *B–D*, × 700.)

figured by Krieger (1932, Pl. xv, fig. 1) from Sumatra; it is, however, smaller, and has a more convex ventral margin.

Rather rare.

Genus STAURASTRUM Meyen.

Staurastrum botanense Playfair var. *variabile* Krieger forma (Fig. 17, *D*).

Long. cum sp., 28 μ; sine sp., 14 μ; lat. cum sp., 20–23 μ; isthm., 7–8 μ; zygosp., 14×20 μ.

The individuals observed always had two spines at the end of the arms, whereas the variety first described from Sumatra showed sometimes one, sometimes two. Further, the arms in the present form were more drawn out.

A zygospore was noticed in one instance only; it was roughly ellipsoidal in shape but was not mature (see Fig. 17, *D*). The zygospore of *St. botanense* has not previously been described.

Rather common.

St. botanense in any form has not previously been recorded for South Africa.

Staurastrum cyclacanthum W. and G. S. West var. nov. *non-incurvatum* (Fig. 17, *A–C*).

Staurastrum processibus aut horizontalibus aut leviter sursum divergentibus, paullum longioribus et denticulis plus numerosis quam in typo.

Long., 30–33 μ; lat. sine proc., 13–14 μ; cum proc., 60 μ; isthm., 7–10 μ.

The possession of an apical ring of six warts each furnished with three spines marks this *Staurastrum* as belonging to the above species (with which

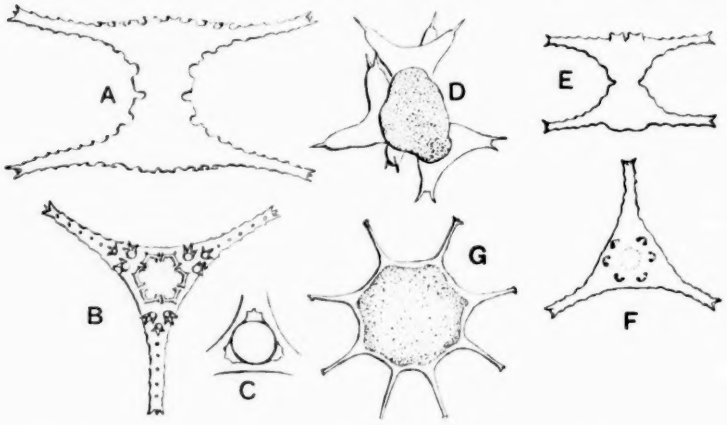


FIG. 17.—*A–C*, *Staurastrum cyclacanthum* var. *non-incurvatum*. *D*, *Staurastrum botanense*. *E–G*, *Staurastrum floriferum*. *G*, zygospore. (All × 750.)

it also agrees in dimensions). The arms in the present variety, however, are a little longer, and possess more denticulations; they are not incurved as in the type, but are either horizontal or they diverge slightly upwards. From the form described by Krieger (1932, p. 197) this variety differs in its shorter arms.

In the collection I examined from Weltevreden West Pan in the Transvaal there was a very similar *Staurastrum* which I named *St. sub-Johnsonii* var. *minor* (Rich, 1932, p. 179, fig. 16, *C*). Very few individuals were then seen, and I consider now it was misnamed and that it should be included in the above variety of *St. cyclacanthum*.

Rather common.

Recorded for the Transvaal.

Staurastrum dejectum Bréb. var. *patens* Nordst. forma.

Long. cell., 26–28 μ; lat. cum sp., 35–36 μ; sine sp., 25–28 μ.

Isthmus not elongated; spines small; lateral margins slightly concave in end-view.

Rather rare.

Recorded for British East Africa.

Var. *inflatum* West; Borge, 1930, fig. 40.

Long. cell., 34 μ; lat., 30 μ; isthm., 10 μ; long. spin., 5–6 μ.

Rather rare.

Staurastrum floriferum W. and G. S. West var. nov. *variabile* (Fig. 17, *E–G*).

Var. minor, denticulis in processibus plus numerosis. Zygosporis globosis spinis longis in apicem trifurcatis praeditis.

Long. cell., 17–20 μ; lat. cum proc., 30–40 μ; isthm., 5–6 μ; zygospor. sine sp., 20 μ; cum sp., 42 μ.

The apex of the semi-cell is slightly elevated and furnished with a pair of emarginate verrucae; the processes are horizontal, and terminate in three minute teeth. The processes vary in length and in the number of their denticulations (4–7). This variety is smaller than the type, and appears to have more denticulations on the arms.

The zygospore is spherical and is furnished with long spines trifurcate at the tips. Zygospores of *St. floriferum* have not previously been described.

Rather common.

This species has not hitherto been recorded for South Africa.

Staurastrum leptodermum Lund. forma *minor* Lütkemüller (Fig. 18, *A*).

Long. cell. (sine protub.), 27–34 μ; lat. cum. sp., 37–40 μ; isthm., 14–15 μ.

Several different forms of this species were observed, one definitely resembling Lütkemüller's figure * of f. *minor*, the apex being slightly retuse, though it did not quite agree with it in dimensions. (W. and G. S. West also describe a f. *minor* from Angola, but that has angles not so markedly produced.)

Rather rare.

Forms intermediate between the type and var. *Ikapoae* (Schmidle) W. and G. S. West, are also present.

Var. *sub-corniculatum* Rich forma nov. (Fig. 18, *B*).

Long. cell., 27 μ; lat., 40 μ; isthm., 11–12 μ.

Possessing short arms, and therefore resembling this variety, but smaller than the individuals found in the Weltevreden West Pan (Transvaal).

Rather rare.

* Lütkemüller, J., 1900. Desmidiaceen aus den Ningpo Mts. in Central China, Tab. VI, fig. 30.

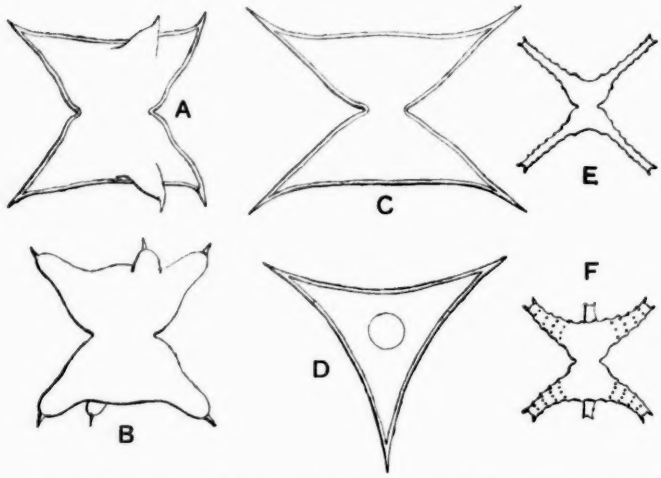


FIG. 18.—*A*, *Staurastrum leptodermum* f. *minor*. *B*, *St. leptodermum* var. *sub-corniculatum* forma. *C*, *D*, *St. sub-curvatum*. *E*, *St. tetracerum* var. *sub-excavatum* forma. *F*, *St. pseudotetracerum*. (All × 750.)

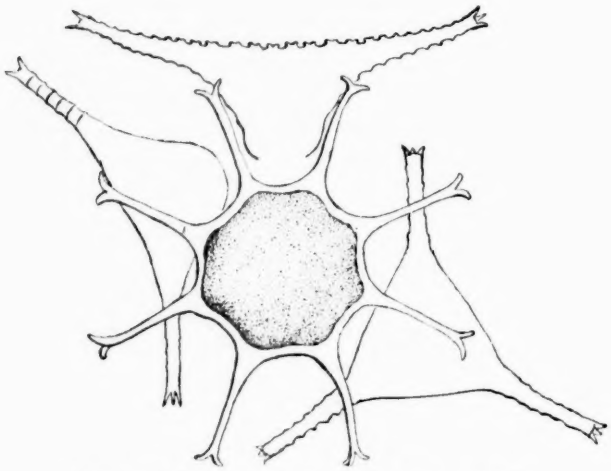


FIG. 19.—Zygospore of *St. Manfeldtii* forma. (× 750.)

Staurastrum Manfeldtii Delp. *forma* (Fig. 19).

Long., 40–44 μ; lat. cum proc., 66–80 μ; isthm., 10 μ; zygospor. sine sp., 30 μ; cum sp., 80 μ.

This is probably a form (or variety) of *St. Manfeldtii* and is identical with that found in the Transvaal (Rich, 1932, p. 176). Not enough individuals were seen to enable a detailed drawing to be made (Fig. 19 is merely a sketch). The form present in Old N'gamo differs from the type in the apex being nearly straight and not slightly convex.

A few zygospores were observed; they were spherical and were furnished with long bifurcate spines which measured more than 20 μ in length. The zygospores of *St. Manfeldtii* have not previously been described.

Rather rare.

Recorded for the Transvaal.

Staurastrum mucronatum Ralfs; W. and G. S. West, Alg. Ireland, 1902, fig. 31.

Long., 27–28 μ; lat. sine sp., 26–27 μ; isthm., 6–7 μ.

Rather rare.

Not previously recorded for South Africa.

Staurastrum pseudo-tetracerum (Nordst.) W. and G. S. West. (Fig. nostr. 18 *F*.)

Long., 16–20 μ; lat., 24–26 μ; isthm., 5 μ.

The individuals seen agreed with those found by the Wests in Madagascar and Ceylon.

Staurastrum sub-curvatum sp. nov. (Fig. 18, *C*, *D*).

Long. cell., 29–30 μ; lat., 44–50 μ; isthm., 9–10 μ.

Staurastrum mediocre, profunde constrictum, sinu fere rectangulari; semicellulis lunatus, inter se divergentibus, apicibus leviter concavis, angulis in spinis divergentibus attenuatis; a vertice visis semicellulis triangularibus, marginibus leviter concavis, angulis in spinam scabrem protusis.

This *Staurastrum* bears a resemblance to *St. megacanthum* Lund. var. *Scoticum* W. and G. S. West which, in the opinion of Dr. Carter (West and Carter, 1923, p. 21), might well be considered a form of *St. curvatum* West.

The spines are not so long as in *St. curvatum* and the isthmus is not so open.

Rare.

Staurastrum sub-radians sp. nov. (Fig. 20, *A–B*).

Staurastrum sub-parvum, modice constrictum, corpore semicellulae ca. $1\frac{1}{2}$ plo long. quam lat. (processibus exclusis); semicellulis cupulae

formibus, margine dorsali convexa, angulis in processibus brevibus tridentatis 6 sursum extrorsumque spectantibus protrusis, processibus seriebus 3 vel 4 denticulorum iis inferioribus emarginatis praeditis; a vertice visis circularibus, processibus radiantibus 6, circulo granulorum 6 prope isthmum.

Long., 30–34 μ; lat. cum proc., 40 μ; isthm., 11–12 μ.

Cells rather small, body of cell about $1\frac{1}{2}$ times longer than broad (exclusive of processes). Moderately constricted. Semi-cells cup-shaped,

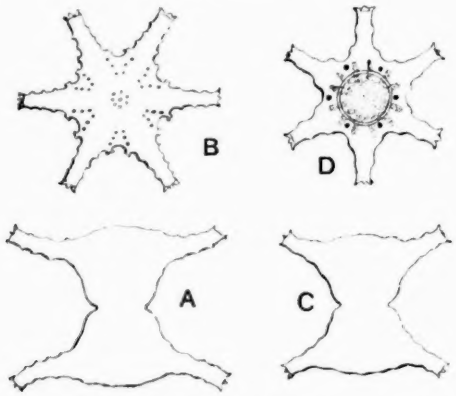


Fig. 20.—*A*, *B*, *Staurastrum sub-radians*. *C*, *D*, var. nov. *simplex*. (All × 750.)

dorsal margin convex, angles produced to form six short processes, which are upwardly and outwardly directed and end in three or four small teeth; processes with three or four series of denticulations. Vertical view circular, with six radiating processes; a circle of 6 granules visible near the isthmus, and, when viewed from a higher focus, there is a central granule surrounded by a circle of others.

There is a strong resemblance to *St. radians* W. and G. S. West (from the United States), but the *Staurastrum* now under consideration is smaller, and its arms are not horizontal. It also resembles *St. dicodon* Bruhl and Biswas (from North-East India) and *St. mutabile* Turner (from East India), both of which species, however, appear to have horizontal processes.

Rather common.

Var. nov. *simplex* (Fig. 20, *C*, *D*).

Var. paullum minor, processibus seriebus denticulorum 1 vel 2 solum praeditis.

Long., 28–30 μ; lat. cum proc., 34–37 μ; isthm., 10 μ.

This variety is slightly smaller than the type, and possesses only two series of denticulations (sometimes one) on the processes.

Rather common.

Staurastrum tetracerum Ralfs var. *sub-excavatum* Grönblad * forma (Fig. 18, *E*).

Long. sine proc., 8–10 μ; lat. cum proc., 26–34 μ; isthm., 3 μ.

The present form comes very near to *St. excavatum* W. and G. S. West, specially in the form of its excavated apex, but it is smaller and the arms are more divergent. The sinus is open, with a minutely excavated apex. It is bi-radiate, and is very similar to *St. gracillimum* W. and G. S. West var. *biradiatum* W. and G. S. West, as figured by Bohlin (1901) and Krieger (1930), but it is not like the original figure of the Wests for this variety. On the whole it seems best to classify it as above.

Common.

The type recorded for Equatorial Africa, the Transvaal, and the Knysna Forest.

Staurastrum Tohopekaligense Wolle; Smith, 1924, Pl. 20, figs. 6 and 7.

Lat., 50 μ; isthm., 14 μ. All nine processes of equal length. A species which exhibits considerable variation.

Rather common.

Recorded for Victoria Nyanza.

Var. *trifurcatum* W. and G. S. West (Fig. 21, *A*, *B*).

Long., 36 μ; lat. sine proc., 30–34 μ; isthm., 13–14 μ.

Three processes in the lower whorl; two spines at the end of all nine processes.

Rather rare.

Recorded from the Transvaal.

Var. *brevispinum* G. M. Smith forma nov. (1) (Fig. 21, *C*, *D*).

Long., 26–30 μ; lat. sine proc., 20–22 μ; isthm., 12–14 μ; zygospor., sine sp., 30 μ; cum sp., 52 μ.

The upper whorl consists of six slender processes about 20 μ long, and the lower whorl of three shorter ones, in this latter respect differing from all described forms and varieties of this genus. The short arms vary very much in length; sometimes they are only 6–7 μ long. The processes are trifurcate or bifurcate with short spines. The surface is scrobiculate, and the scrobiculations are arranged regularly.

A zygospore was observed; it was spherical, with long slender spines, nine or ten of which were visible round the margin. The zygospore of

* Grönblad (1921, p. 62) says he does not feel sure that his variety is correctly placed under *St. tetracerum*.

St. Tohopekaligense, or any of its varieties, has not hitherto been described.

Rather common.

Forma nov. (2) *hexagonum* (Fig. 21, *E*, *F*).

Long. cell. (sine proc.), 28–32 μ; cum proc., 44–50 μ; lat. (sine proc.), 20–23 μ; cum proc., 44–46 μ; isthm., 12–16 μ.

St. Tohopekaligense is said to have six processes in the upper whorl and either three or nine in the lower whorl; in the present form there

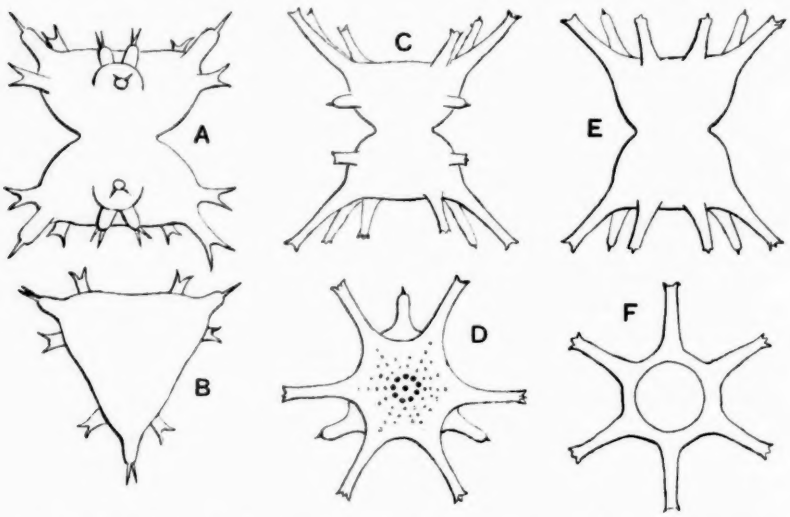


FIG. 21.—*Staurastrum Tohopekaligense*. *A*, *B*, var. *trifurcatum*. *C*, *D*, var. *brevispinum* forma nov. *E*, *F*, var. *brevispinum* forma *hexagonum*. (All × 750.)

are only six processes altogether. In the form last described (see above) the processes in the lower whorl were much smaller than usual, and it is therefore not surprising that some individuals should be found with the lower whorl altogether missing.

The processes taper very slightly, and end in three small teeth.

Not uncommon.

Staurastrum Wildemani Gutw. (Fig. 22, *A–C*).

Long. cell., 57–58 μ; lat. sine sp., 54–60 μ; cum sp., 84–112 μ; isthm., 20–23 μ; zygospor., 60–74 μ; cum sp., 130–147 μ.

The punctulations are fine, and difficult to see.

The apex of the semi-cell is slightly convex.

From *St. longispinum* (Bailey) Archer this *Staurastrum* differs in its

smaller size, its more deeply constricted isthmus, and in the marked divergency of its spines. It also comes near *St. subtrifurcatum* W. and G. S. West. The zygospore is spherical in form, furnished with long, pointed spines, of which about nine or ten are visible round the margin. The zygospores of *St. Wildemani* have not previously been described.

Rather rare.

Not previously recorded for South Africa.

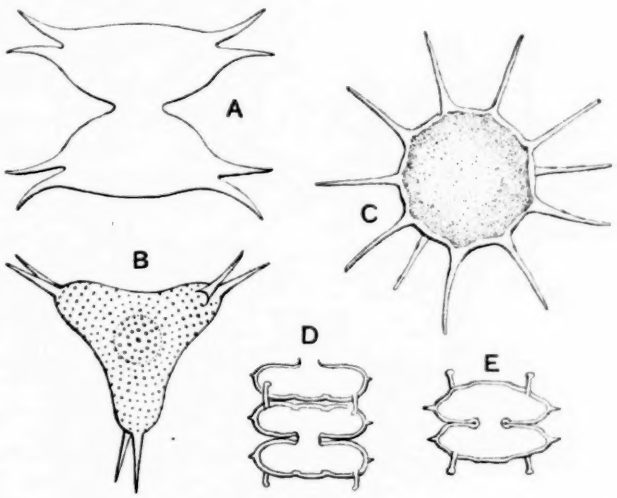


FIG. 22.—*A–C, Staurastrum Wildemani* (× 350). *D, E, Onychonema laeve* var. *micracanthum* (× 750). *E,* forma nov.

Genus COSMOCLADIUM Bréb.

Cosmocladium sub-ramosum Schmidle (= *C. pusillum* Hilse.).

Long. cell., 11–14 μ; lat., 10–11 μ; isthm., 3 μ; crass., 6 μ.

Colonies usually consisting of only four cells.

Rather common.

Not previously recorded for South Africa.

Genus SPHAEROZOSMA Corda.

Sphaerozosma granulatum Roy and Biss.

Long. cell., 8–10 μ; lat., 8–10 μ.

Rather rare.

Recorded for the Transvaal.

Genus Onychonema Wallich.

Onychonema laeve Nordst. var. *micracanthum* Nordst. (Fig. 22, *D*).

Long. cell., 14 μ; lat. sine sp., 24 μ; isthm., 4 μ.

The small spines are quite horizontal. There is no ornamentation on the cell-wall.

Rare.

Previously recorded for Nyasa and the Transvaal.

Forma nov. (Fig. 22, *E*).

Long. cell., 14–18 μ; lat. sine sp., 23–25 μ; isthm., 4 μ.

The outline of the semi-cell is undulate, in this respect differing from all previously described forms or varieties of *O. laeve*. The small spines are horizontal, or slightly inclined.

Rather rare.

Genus Hyalotheca Ehrenb.

Hyalotheca dissiliens (Sm.) Bréb.; Allorge, 1930, Pl. xv. fig. 9.

Zygospores present, 20 μ in diameter.

Rather rare.

Recorded for Equatorial and South Africa.

Hyalotheca mucosa (Mert.) Ehrenb. var. *minor* Roy and Biss.

Long., 15 μ; lat., 12 μ.

Rare.

Recorded for the Transvaal.

Genus Desmidium Agardh.

Desmidium Baileyi De Bary var. *coelatum* (Kirchn.) Nordst.

Lat. cell., 24–30 μ; zygospor., 16 × 26 μ, 18 × 30 μ.

Some of the cells were quadrate, some triangular, in end-view, the former being the commoner. The triangular cells were precisely similar to those found in the Transvaal in 1932.

Zygospores were present.

Rather common.

Desmidium Swartzii Ag.; West and Carter, Desmids V, Pl. clxiii, fig. 5.

Long. cell., 17–18 μ; lat., 34–36 μ.

Rather rare.

Recorded for Central Africa and Madagascar.

CLASS II. HETEROKONTAE.

Genus Chlorobotrys Bohlin.

Chlorobotrys regularis (West) Bohlin.

Cells 20 μ in diameter, with several relatively large chloroplasts; either solitary or in twos or fours.

Rather common.

Genus Peroniella Gobi.

? *Peroniella* sp. (Fig. 23, *A*).

Cells, 6–8 μ wide, 8–10 μ long; with stalk, about twice as long. Growing on dead *Spirogyra* filaments.

Rare.

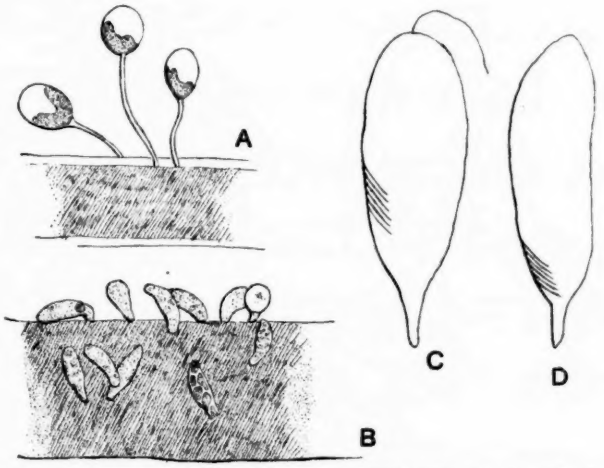


Fig. 23.—*A*, *Peroniella* sp. *B*, *Characiopsis minuta* forma. *C*, *D*, *Euglena* sp. (*A*, *B*, × 750; *C*, *D*, × 350.)

Genus Characiopsis Borzi.

Characiopsis longipes Borzi; Pascher, Süsswasserflora, Heft xi, fig. 50.

Cells, 4 μ wide, 16 μ long without stalk.

Rare.

Characiopsis minuta Borzi forma (Fig. 23, *B*).

Long., 11–15 μ; lat., 4 μ.

Apex obtuse, no starch. Stalk wide, narrowing to the base.

Growing on *Spirogyra* and *Mougeotia*.

This minute alga shows some resemblance to *Characium curvatum* G. M. Smith; it has, however, several chloroplasts, contains no starch, has not an acute apex, and is epiphytic on different hosts.

Rather rare.

Characiopsis pyriformis Borzi; Pascher, 1925, fig. 47, *a*.

Long., 22–30 μ; lat., 10–11 μ.

Growing on *Oedogonium*, also on *Utricularia*.

Rare.

Genus Ophiocytium Naegeli.

Ophiocytium cochleare A. Br. forma.

Cells solitary, 6 μ wide, often many times coiled.

Spine longer than in the type, but not so long as in *O. Lagerheimii* Lemm.

Rare.

Recorded for the Transvaal.

Genus Botryococcus Kützing.

Botryococcus Braunii Kützing.

This alga seems to be widespread in South Africa.

Rather rare.

Botryococcus protuberans W. and G. S. West.

Possibly only a stage in the preceding.

Rather common.

Recorded for South Africa.

CLASS III. CHRYSOPHYCEAE.

Genus Dinobryon Ehrenberg.

Dinobryon sp. Only a small fragment seen.

CLASS IV. BACILLARIALES (DIATOMALES).

A class rather poorly represented in the present collection; see Introduction, p. 111.

CLASS VI. DINOPHYCEAE (PERIDINEAE).

Genus Peridinium Ehrenberg.

Peridinium tabulatum (Ehr.) Clap.-u-Lachm.

Long., 50–54 μ; lat., 54–58 μ.

Rather rare.

Previously recorded for South Africa.

CLASS VIII. EUGLENINEAE.

Genus Euglena Ehrenberg.

Euglena sp. (Fig. 23, *C*, *D*).

Though not uncommon it was not in a good condition for determination.

Long., 127–130 μ; lat., 32–45 μ.

The individuals observed all had a distinct caudal appendage. They resemble *E. caudata* Hübner, but I can find no detailed description of this species.

Genus Phacus Dujardin.

Phacus orbicularis Hubner var. *minor* Fritsch and Rich.

Long., 34 μ; lat., 26 μ.

Not common.

Recorded for South Africa.

Genus Colacium Ehrenberg.

Colacium vesiculosum Ehrenb.

Long. cell., 22 μ; lat., 11 μ. Sides often nearly parallel. Stalk, from one-half to one-third the length of the cell.

Attached to a Rotifer.

Similar to a *Colacium* observed in the Transvaal (Rich, 1932, Fig. 18, *C*, *D*), but with slightly longer stalks.

Rare.

CLASS XI. MYXOPHYCEAE (CYANOPHYCEAE).

Genus Microcystis Kützing.

Microcystis flos-aquae (Wittr.) Kirchn.; Geitler, 1932, fig. 59, *f*, p. 136.

Rather common.

Common in South Africa.

Genus Aphanocapsa Naegeli.

Aphanocapsa elachista W. and G. S. West var. *conferta* W. and G. S. West.
Cells rather densely packed; 1·5 μ in diameter.
Rather common.
Previously recorded from South Africa.

Genus Aphanothece Naegeli.

Aphanothece stagnina (Sprengel) A. Br.
Cells, 8 × 5 μ, blue.
Rather rare.

Genus Gomphosphaeria Kützing.

Gomphosphaeria lacustris Chodat.
Cells, 3 μ wide.
Rather rare.
Previously recorded for South Africa.

Genus Coelosphaerium Naegeli.

Coelosphaerium confertum W. and G. S. West.
Cells just over 2 μ wide, colony about 30 μ.
Rare.
Recorded from Central Africa.

Coelosphaerium Naegelianum Ung.
Cells, 6–7 μ long, in pairs in a hollow sphere, 90 μ in diameter.
Rare.

Coelosphaerium Goetzii Schmidle.
Colony, 30–40 μ in diameter; cells, 4 μ.
Rare.
Recorded from Tropical Africa.

Genus Hapalosiphon Naegeli.

Hapalosiphon fontinalis (Ag.) Born (Fig. 24, *A*, *B*).

Trichome pale blue, sheath laminated though narrow, main filaments 8–12 μ thick, richly branched, branching usually on one side only. The branches are slightly narrower than the main filament. The cells are generally in a single row. This very polymorphic species is allied to *H. intricatus* W. and G. S. West, and *H. hibernicus* W. and G. S. West, in both of which, however, the cells of the branches are more elongated than in *H. fontinalis*.

Rather common.

This cosmopolitan species has not previously been recorded for South Africa, though both the allied species have.

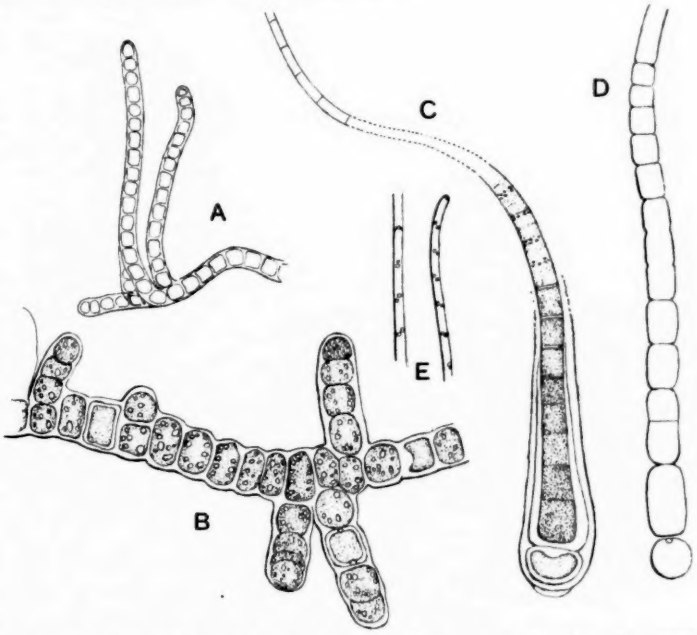


FIG. 24.—*A, B, Hapalosiphon fontinalis. C, Calothrix fusca. D, Calothrix scytonemicola. E, Lyngbya bipunctata*?. (*B, C, D,* × 750; *A,* less highly magnified.)

Genus CALOTHRIX Agardh.

Calothrix fusca Born. et Flah. (Fig. 24, *C*).

Filament at the swollen base 14–15 μ wide, further up 5–6 μ wide. Outer sheath colourless or pale yellow; the inner sheath, which extends for only a short distance, is a dingy brown.

Growing in the main on the clumps of *Gloeotrichia Pisum*, but also on other plants.

Rather common.

Previously recorded for South Africa.

Calothrix scytonemicola Tilden. (Fig. 24, *D*).

Filaments 7–8 μ wide, solitary or in groups. Heterocysts basal, solitary, 6–8 μ wide.

Rare.

Not previously recorded for South Africa.

Genus Gloeotrichia Agardh.

Gloeotrichia Pisum Thuret; Frémy, 1930, fig. 244.

The rounded clumps of this *Gloeotrichia* were often nearly covered with *Calothrix fusca*.

Rather common.

Recorded for Madagascar.

Genus Aulosira Kirchner.

? *Aulosira implexa* Born. et Flah.

I do not feel sure about this determination, though the filaments I have examined agree with the description given in Geitler's "Cyanophyceae," p. 675.

Very rare.

Recorded from Madagascar.

Genus Anabaena Bory.

Anabaena inaequalis (Kütz.) Born. et Flah.; Frémy, 1930, fig. 301.

Cells 3·5–4·5 μ wide, about equally long or a little longer. Heterocysts round or elongated, the same width as the ordinary cells; up to 10 μ in length. Spores cylindrical, remote from the heterocysts, solitary or two together; 4×13 μ, 5×11 μ, but the few found were not mature.

Rather rare.

Recorded for South Africa.

? *Anabaena oscillarioides* Bory.

The spores observed were shorter than those figured for the type, but they were not ripe; Playfair (1916) figures some spores like those now present.

Cells 7 μ wide, as long as broad; heterocysts *circa* 9 μ, round or elongated; spore, adjacent to heterocyst, 10 μ wide, 14–20 μ long.

Rather rare.

Recorded for Africa.

Genus Cylindrospermum Kützing.

Cylindrospermum stagnale (Kütz.) Born. et Flah.; Geitler, 1932, fig. 520, *C.*

The spores were immature.

Rare.

Not previously recorded for Africa.

Genus Phormidium Kützing.

Phormidium tenue (Menegh.) Gomont; 1892, Pl. iv, fig. 24.

Few-celled trichomes a little over 1 μ wide; slightly constricted between the cells; end cell pointed.

Rather rare.

Recorded previously for South Africa.

Genus LYNGBYA Agardh.

Lyngbya aerugineo-caerulea Gom.

Septa sometimes granular.

Not very common.

Widely distributed in Africa.

Lyngbya (?) *bipunctata* Lemm. (Fig. 24, *E*).

Filaments loosely and irregularly twisted, not forming definite spirals. Trichomes about 1 μ wide. Cells longer than wide, partitions marked by the presence of two granules. End cell rounded.

Not uncommon.

Recorded for Lakes Nyasa and Tanganyika.

Lyngbya spp.

Other narrow *Lyngbyas* are present but most of them have lost their distinctive features.

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A NEW LAMELLIBRANCH FROM THE UPPER DWYKA BEDS OF SOUTH-WEST AFRICA.

By F. R. Cowper Reed, Sc.D., F.G.S.

(Communicated by S. H. Haughton.)

(Read October 17, 1934.)

(With Plate V.)

Dr. S. H. Haughton, Director of the Geological Survey of the Union of South Africa, recently sent me for examination three fossils from the Upper Dwyka Shales of the neighbourhood of Haib in South-West Africa which were mentioned * in a paper by him and Mr. H. F. Frommurze on the Karroo beds of the Warmbad district. One of these specimens (labelled S.W. 139) was described by them as a "*Mytilus*-like lamellibranch" and provisionally identified as *Myalina* (?) sp. Another very poor and fragmentary specimen (S.W. 140) probably belongs to the same species. The third specimen (S.W. 138), which was described by them as "the mould of part of a coiled shell presumed to be a gastropod," is too poor for any satisfactory determination, but it may be part of a pleurotomarioid or euomphaloid shell. The best preserved specimen is that (S.W. 139) which was termed "*Myalina* (?) sp.," and it is fully described below; it occurs in a fine-grained brownish flagstone weathering reddish-yellow.

Aphanaia haibensis sp. nov. Plate V.

The greater part of a large obliquely elongated mytiliform left valve and part of the beak and cardinal region of the right valve of the same shell are exposed on the flat surface of a slab of rock (S.W. 139); the shell-substance is mostly preserved, but the anterior margin of the left valve has the lower part broken off and the end of the valve is also missing, though from the curvature of the rugae on the surface we are able to determine the shape of the shell. It appears that we have the interior of an open shell exposed, the two valves remaining in their natural position.

* Haughton and Frommurze, Trans. Geol. Soc. South Africa, vol. xxx, 1928, pp. 139 and 141.

The beaks are terminal, and the shell gradually expands in width posteriorly. In the case of the left valve the anterior margin is seen to arch gently forward in a broad curve to the point where it is broken off; the hinge-line (cardinal margin) is straight and makes an angle of about 80° with the anterior margin at the beak, which is bluntly pointed, but not swollen or projecting. The hinge-line is about two-fifths the entire length of the shell, and forms a simple junction with that of the other valve without any trace of teeth or of a ligamental area. Behind the hinge-line the margin of the shell makes a very obtuse angle (140°–150°) and runs nearly straight back for some distance before curving sharply round in a subparabolic curve to form the posterior end of the shell. The surface of the valve seems to have been gently convex in the umbonal region and along an axial line somewhat nearer the anterior than the posterior margin, the posterior upper third of the valve being flattened but not forming a wing. The concentric rugae, which number 20–25, are coarse, strong, rounded and subequal in size, but increase in width towards the posterior end and became weak or obsolete on the posterior upper third of the valve, and they seem to be broken up or even to divide irregularly near the posterior upper edge, though this may be due to the mode of preservation of the fossil; the curvature of the rugae increases distally, and they apparently meet the anterior margin at an acute angle and are directed similarly to the hinge-line at an angle of 15°–20°; a few concentric striae are also present near the upper posterior edge of the valve; and some traces of a few narrow radial ridges or thick lines crossing the concentric rugae near the umbo are obscurely visible. The cast of an oval muscle-scar, probably the anterior muscle of the foot, is preserved in the umbonal region of this valve.

The beak of the right valve, which is in apposition to that of the other valve, is only partly preserved, and scarcely seems to be higher or larger than its fellow, so that it may be suspected that the shell is nearly or quite equivalve. The cardinal portion of this valve only is preserved as a narrow strip, but it shows concentric rugae like those in the other valve, and its line of contact with the other valve is clearly seen. In the umbo there is a subcircular cast of a muscle-scar for the foot, but it is only about half the size of that in the left valve.

Dimensions.—Length of shell (estimated) *c.* 85 mm.
Width ,, ,, *c.* 45 ,,

Remarks.—It was at once recognised that this shell bore a great resemblance to De Koninck's genus *Aphanaia* * from the Permo-Carboniferous beds of New South Wales, and a comparison with the type-specimen of

* De Koninck, "Descr. Palaeoz. Foss. N.S. Wales, 1877" (translated by David and Dun), Mem. Geol. Surv. N.S.W. Palaeont. No. 6, 1898, p. 238.

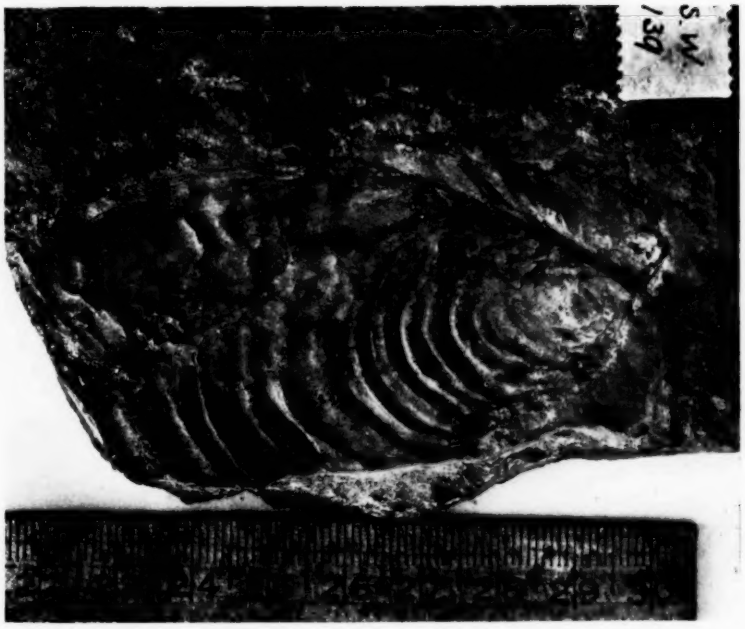

Photo: H. Lang.

Aphanaia haibensis sp. nov., Reed.
(Scale in cms.)

Aphanaia Mitchelli (M'Coy) * in the Clarke Collection in the Sedgwick Museum, Cambridge, strongly supported this view, though our African specimen does not show the striated ligamental area and we cannot be certain that the shell is inequivalve. The non-exposure of the ligamental area is, however, due to the opened-out condition of the shell, the valves lying flat and side by side in the same horizontal plane and showing only the interior with the hinge-lines of the two valves in close contact. *Aphanaia Mitchelli* differs from our new species in being less elongate and more convex and in having fewer and coarser concentric rugae on the surface; *A. gigantea* De Kon.† has more the shape of our shell, but possesses much thicker and coarser rugae. The genus has been recognised by Trechmann ‡ in the Maitai beds of New Zealand, but has not been observed in the Salt Range in the Punjab or in the "Agglomeratic Slate" of Kashmir from which the Australian "Permo-Carboniferous" marine fauna has recently been described.§ The occurrence in South-West Africa of *Aphanaia*, as well as of the previously recorded genera *Eurydesma*, *Conularia*, and *Productus*, is additional evidence of the widespread extent of this fauna. It may be stated that it is now widely acknowledged that the beds containing this fauna in India and Australia are of Upper Carboniferous age, and the correlation of the Gondwana System of India, with related formations of other countries which has been adopted by the Geological Survey of India,‖ is supported by strong evidence.

Postscript.—Since the completion of the above notes my attention has been drawn to the description and figures of a New Zealand Triassic shell named *Myalina*? (*Maoria*) *problematica* (Zittel) ¶ which Dr. Otto Wilckens (*op. cit.*) considers as having a "Palaeozoic aspect," and is very similar to species from the Carboniferous of New South Wales attributed to *Mytilus* and *Aphanaia* by De Koninck and M'Coy. The resemblance of our specimen from South-West Africa to Zittel's species is undoubtedly close.

* M'Coy, Ann. Mag. Nat. Hist., vol. xx, 1847, p. 99, pl. xiv, fig. 1; De Koninck, *op. cit.*, p. 239, pl. xxi, figs. 5, 5*a*.

† De Koninck, *op. cit.*, p. 240, pl. xxi, fig. 6.

‡ Trechmann, Geol. Mag. Dec. VI, vol. iv, 1917, p. 56, pl. iv, figs. 1–4. (The generic identification of this New Zealand shell is questioned.)

§ Reed, Palaeont. Indica, n.s., vol. xx, vol. i, 1932, pp. 1–79, pls. i–xiii.

‖ C. S. Fox, "The Gondwana System and Related Formations," Mem. Geol. Surv. India, vol. lviii, 1931, pp. 1–241, pls. i–ix.

¶ Otto Wilckens, "Contrib. Palaeont. New Zealand Trias," Geol. Surv. New Zealand, Palaeont. Bull. No. 12, 1927, p. 13, pl. ii, figs. 3 *a*, *b*, 4, 5, 6.

PRESIDENTIAL ADDRESS.

THE "SOLID" GEOLOGY OF THE KALAHARI.

By A. W. Rogers.

(Read March 20, 1935.)

The Kalahari is a very large sand-covered region extending from the Zambezi to the Orange River; it is about 1000 miles wide in the north and it narrows southward, like the continent it lies in. It is a formidable obstacle in the endeavour to connect the "solid" geology of South-West Africa with that of the Transvaal and Rhodesia. Thirty years have passed since Dr. Passarge's book *Die Kalahari* (1)* was published, and it is of interest to review the work done since then. The chief sources of information are the reports and maps of the Rhodesian Geological Survey, including Mr. Macgregor's observations along the proposed railway route to South-West Africa, the work of Professor Jaeger and others in South-West Africa, the Cape Geological Commission's reports and the papers by Dr. A. L. du Toit. In 1930 Mr. A. S. Vernay took a party from Gaberones to the Okavango delta and the Zambezi for the study of the fauna and flora, and he kindly invited me to accompany them; I was thus able to visit the Ghanzi district and some other places where rocks crop out that were described by Dr. Passarge but the relation of which to formations in the Union was in doubt. Owing to the absence of fossils from these rocks and the great distances between them and possible correlatives in the Union we have to rely on lithological character and structure; the result is not very satisfactory as regards the pre-Karroo formations, and at present there is no obvious solution of the chief difficulties.

In 1914 Mr. Lightfoot (2) saw that the Batoka basalts, of Stormberg age, lay directly on the old gneiss on the Bechuanaland-Rhodesian border west of Wankie; about 100 miles farther west, on the right bank of the Linyanti River between Kavimba and Lambeye, gneiss crops out on the slope to the river below basalt, which is capped by silcrete. The outcrops and fragments of gneiss were seen for a few hundred yards, and there is some variety in the three specimens brought away, chiefly due to the varying quantities of quartz and epidote; the felspars are orthoclase and

* The numbers refer to the list at the end.

albite, and the biotite has been altered to chlorite. Dr. Passarge (3) described outcrops of granite gneiss at Okwa, in the bed of the river about 100 miles above where Mr. Vernay crossed it at a place with many outcrops of surface limestone but no sign of the underlying rock. The outcrops at Okwa, on the Linyanti and on the Rhodesian border, seem to be the only known occurrences of the older granites inthe Kalahari north of the Molopo, and the rocks in which they are intrusive are not known. Dr. Curson, who was in the Okavango delta in 1930 and 1931, kindly brought me some rocks from it; amongst them was a coarsely crystalline marble from Mukembe (below Andara) containing much brown biotite, quartz, and white mica. Dr. Passarge described greywackes (4) in that neighbourhood, rocks which he placed in the Ghanzi group. It seems likely that there is also an outcrop of the pre-Ghanzi Archaean, highly metamorphosed sediments. On the south side of Ngami, amongst the scattered outcrops of the rocks to which Dr. Passarge gave the name Ngami beds and regarded as of post-Ghanzi age, I found a piece of typical mica-schist, quite unlike any outcrop that Dr. Passarge described or that I could find; it consisted of large flakes of white mica and a little quartz, and it did not seem to be a rock that the natives would use, though there are many chipped flakes of chalcedony and silcrete lying about in the neighbourhood. There may be a mass of Archaean rocks under the sand not far off; an outcrop would not have escaped Dr. Passarge's careful survey of the south side of Ngami. On the present eroded edge of the Kalahari the old granite plays an important part in the north-east, south-east, and north-west, and a minor part near the Orange River. The Swaziland System is represented only in the south, at Matlapaning, Kuie Pan, Scheurberg and near the Orange River. The Witwatersrand and Pongola Systems apparently have no part in the Kalahari structure, but the Ventersdorp and Transvaal-Nama Systems, very important in the south-east and south-west, cannot be definitely recognised in the great sandveld north of the Molopo (4a). Dr. Passarge's Ngami beds are more like the Transvaal Waterberg beds than the rocks of the Transvaal-Nama System as developed in the Transvaal and Cape Province.

Dr. Passarge's description (5) of the Ghanzi beds (Chanseschichten) has led geologists (6) who have had occasion to mention them to class them with the pre-Witwatersrand formations, though Passarge himself says that in petrographical character they resemble Palaeozoic greywackes (7), while he groups them in the Primary formations along with the Swaziland and Kheis beds. Before I saw them I thought they were to be included in what the Geological Survey of the Union calls the Swaziland System, consisting of sedimentary and volcanic rocks older than the Witwatersrand and Pongola Systems. I first saw them in depressions between the sand-

bults two miles east of van Zyl's Cutting (Passarge's Gagam) in the Ghanzi district. They are purplish-red quartzites weathering with a softer brown crust. Half a mile south of the track at this place there is a pan on a flat quartzite surface; these rocks are banded owing to the size of their component grains, and false bedding is often conspicuous. The dips are low, not over 10°, towards E. 15° N. and E. 10° S.; the rocks are closely jointed E. 40° N., E. 30° S. and E. 40° S. A well was being sunk at the time of our visit; it was 60 feet down in the same kind of quartzite without intercalations of shale. At van Zyl's Cutting the purplish quartzite forms a flat surface of some two acres in which a small water-hole has been made by prizing out the quartzite and blasting. The dip is 15° towards N. 10° E. and there are many joints N. 35° E., E. 30° S., S. 20° E. with variations, and there is a rough cleavage at places trending from 15° to 25° N. of E. The smooth quartzite surfaces have been grooved by natives sharpening or grinding things on the rock. In the neighbourhood of Gagam I reckoned that there are at least 1000 feet of these purplish quartzites, and they reminded me very strongly of the Matsap beds on the Molopo and in the Langeberg ranges, an impression that was strengthened by the rocks seen in wells elsewhere in the Ghanzi district and in the outcrops and wells in Olifants Kloof and other places between the Ghanzi district and Gobabis. There is, however, an important point of difference in the presence of carbonates in some of the Ghanzi beds, for calcareous rocks have not been recorded from the Matsap beds nor, I think, from the Waterberg formation in the Transvaal. In the Ghanzi district the only rocks seen in wells and outcrops, excepting superficial sands, limestones, and silcretes, belong to the Ghanzi beds; the occurrences noted are in an area extending about 65 miles from Gagam westwards to Quagganai and 50 miles northwards to Mochumi Pan, most of them being in wells under a cover of surface limestone up to 10 feet thick. Large fragments of the characteristic quartzite are not uncommon, but good outcrops were only seen at Gagam, and they are low lying; for so hard a rock this is a peculiar fact, and the large smooth surfaces at van Zyl's Cutting made me expect to find glacial scratches and remnants of the Dwyka tillite, as on the similar surfaces of the Matsap quartzites on the Molopo and elsewhere 300 miles to the south. I did not find any evidence of the tillite, and the only foreign pebbles seen were two made of the Kwebe porphyry and one of a diabase; these were picked up in a laagte on Monyalatsela, which is said to lead to the Okwa River. No pebble beds or isolated pebbles were seen in the Ghanzi district; intercalations of shale were seen in wells at Gemsbok Pan, Quagganai, Sunnyside, and Kgoutsa, and these shales are roughly cleaved; clay-pellet conglomerates are occasionally seen. Though I saw no pure limestones in these beds, a noticeable amount of carbonates is in some of them; a

rock from the Kgoutsa well proved to have 28 per cent. of carbonates, of which magnesium carbonate formed a considerable part. Dr. Passarge (9) recorded many occurrences of calcareous greywacke, and, from Audji and near the Kwebe hills, limestone; he also noted the frequent presence of detrital grains of felspar. The carbonates in the Ghanzi beds may be regarded as the source of the surface limestones so often seen in the district in contrast to the area made of the Kwebe porphyry farther north. Professor Kalkowsky carried out microscopical work on Dr. Passarge's specimens from Ghanzi and the details are given in Appendix V. of Passarge's book; my own observations, though made on rocks from other localities in the district, confirm those of Kalkowsky in finding that felspars from granitic rocks are general, but in some of the rocks collected in 1930 there are fragments of two other kinds of igneous rocks of interest; one kind has a ground-mass almost opaque with iron oxides, and it contains small crystals of plagioclase near andesine; its source is not known; the other kind is made of quartz, felspar, and iron ores with a microgranitic structure and is very like the matrix of the Kwebe porphyry; the albite-oligoclase crystals in the latter rock might have provided many of the felspar grains seen in the quartzites. The quartzites containing these detrital grains of volcanic rocks came from Gagam, from a well about 4 miles E.N.E. of Sunnyside, from an outcrop 17 miles from Sunnyside on the road to Gemsbok Pan, and from Kgoutsa 30 miles west of Sunnyside. A felspathic quartzite from the well at Sunnyside is very fine grained, and no fragments of the volcanic rocks were detected in it. The larger grains in the Gagam and other quartzites in which the volcanic rocks were seen range up to 0·5 mm. in diameter. The grains are mostly angular; even the large ones are not well rounded. The microcline and orthoclase grains are cloudy, but the plagioclase is clear. The quartz grains are rarely strained. Both quartz and felspar grains are adjusted in shape by solution at their contacts, and the matrix is in large part redeposited quartz and felspar in crystalline continuity with neighbouring grains.

Dr. Passarge describes the geology of the country between Ghanzi and Gobabis, making the Olifants Kloof quartzites part of the Ghanzi beds, and the rocks near Gobabis Ngami beds, which he considered the younger formation (10). I agree with him about the stratigraphical position of the Olifants Kloof rocks, but there seems to me to be no weight in his reason for making the rocks at Gobabis the younger formation. He wrote "Of the greatest importance is the fact that the transverse jointing (Klüftung) which so strongly affects the Ghanzi beds is not observed in the Ngami beds. From that one can conclude that the latter are younger than the former" (11). He remarks upon their general petrographical similarity. Even in one area such an argument must be used with great caution, and where

the areas are separated by several miles it is worthless. Rimann described that region in 1913, but he does not use the term Ghanzi beds; he placed the Olifants Kloof beds in the Upper Nama, under the name of Upper Waterberg, and those near Gobabis he distributed amongst lower horizons of the Nama formation under the names of Lower Waterberg, Fish River, Kuibis, Schwarzkalk, and Basal beds (12). The stratigraphy of the north-eastern part of South-West Africa is not well known, and its study is difficult on account of the isolation of outcrops over a very great area of sandveld. It would be unprofitable to discuss the several possibilities on the present information, but it may be that in South-West Africa, far away from the great intrusions of the Bushveld Complex, there is a less broken record of sedimentation through the Nama and Waterberg periods than we have in the Union. In the region from Ghanzi to Gobabis the rarity or absence of igneous intrusions is striking, and it reminds one of the similar conditions in the region of the Matsap beds in the Cape Province; it is in strong contrast to the state of affairs in the Waterberg region of the Transvaal, where the many basic intrusions are looked upon, in the words of Dr. Hall, as a later manifestation of the Bushveld petrogenic cycle (13).

In May 1929 Dr. Wagner, in the last words he spoke at an ordinary meeting of the Geological Society of South Africa (14), gave us a brief account of the geology of Kanye, drawing attention to the Waterberg beds of that region and the igneous rocks on which they rest, an offshoot of the Bushveld Complex. They pass under the sand west of Kanye; no further work on them has yet been done. The Waterberg beds and the igneous rocks they rest on, belonging to the Complex or to the old granites, together with a capping of Karroo sandstones and basalt, fringe the eastern side of the Kalahari for over 200 miles north of Lobatsi, but the Rooiberg felsites have not been reported from the region.

Dr. Passarge gave the name Kwebe porphyry to the porphyritic rocks of the hills stretching interruptedly for 60 miles from the Mabaleapudi hills (generally known as the Kopjes) to the Kwebe hills (15). The Gubatsa hills and the Goha hills, 170 miles farther to the north-north-east, are made of the same kind of rock. Passarge considered the Kwebe porphyry to be intrusive in the Ghanzi beds and younger than the Ngami beds, but the character of the outcrops in the Kopjes is that of a volcanic series. Though the petrographical character of the rocks in the south-westernmost ten miles of the Kopjes—the only part of the Mabaleapudi-Kwebe hills that I visited—the Goha hills, which were also visited by me, and the Gubatsa hills, specimens from which were given me by Dr. du Toit, are very much the same, there is variety due to the unequal distribution of quartz and felspar crystals. Fine banding is conspicuous in some outcrops, and contorted flow-structure is very well exposed on large surfaces to the east of the track

to Ngami where it passes through the Kopjes. Typical amygdales were not seen, but there are irregularly-shaped, flattened cavities up to a foot in diameter lined with quartz or, in the smaller examples, filled with quartz; these cavities lie parallel to the general direction of the banding, which dips S.E. or S.S.E. at angles up to 40°. A rough cleavage is developed in some of the rock, giving rise to sharp outcrops which remind one of the Dwyka tillite outcrops in the southern Karroo and of the Ventersdorp breccia north of Rietfontein on the Germiston-Pretoria railway. Where the track to Ngami leaves the poort through the Kopjes there are outcrops of fragmental rocks which appeared to me to be volcanic breccias. Dr. Passarge records breccias in connection with the porphyry; he says: "The nature of the so-called dynamometamorphic rocks is still obscure; they consist of porphyry material, in part containing porphyry pebbles (Porphyrgerölle) and may be the infillings of fissures or friction-breccias in the porphyry" (16).

A piece of the porphyry from the south-westernmost hill of the Kopjes is seen in thin section to have a crystalline matrix in which the individual quartz and felspar components are about 0·01 mm. in diameter; the opaque iron ores are in small and large grains; the analysis shows a large proportion of ferric oxide, so much of the iron is probably in the form of haematite. The quartz of the matrix behaves as individual crystals in polarised light over irregular streaks and patches; some muscovite, epidote, and calcite are present. In this matrix there are corroded crystals of felspar and quartz, the latter being the more corroded. The felspars are up to a tenth of an inch in length and they form about 9 per cent. of the rock by volume; they are optically negative, and their least refractive index is 1·53, corresponding to a felspar containing 92 per cent. of albite and 8 per cent. of anorthite; these figures agree well with those obtained by reckoning the amounts of albite and anorthite from the soda and the lime left over after satisfying the carbonic and phosphoric acids in the analysis. The interior of the felspar crystals is slightly clouded, but there often is a narrow coat of clear felspar outside, and in polarised light this behaves similarly to one of the twin components of the cloudy interior. The felspars are not strained, but some of the quartz crystals show strain shadows between crossed nicols. Flow-structure in the matrix is conspicuous round the phenocrysts. A rock from another hill of the Mabaleapudi group is very similar to that just described, but it has a small amount of brown biotite, while that from a third has its felspar crystals less corroded. A specimen from the Gubatsa hills is very like the Kopjes rock; the quartz crystals are not strained.

An analysis of the rock from the south-westernmost hill was kindly made for me by Mr. B. E. Dixon of H.M. Geological Survey; the figures are:—

	I.	II.
SiO_2	72·10	72·56
Al_2O_3	12·04	11·50
Fe_2O_3	4·63	1·94
FeO	0·29	3·02
MnO	0·04	0·11
MgO	0·29	0·74
CaO	1·11	1·10
Na_2O	3·20	3·23
K_2O	5·31	4·18
H_2O over 105	0·00?	0·08
H_2O under 105	0·12	0·14
CO_2	0·34	0·74
FeS_2	0·07	
Cr_2O_3	0·00?	
P_2O_5	0·10	0·12
TiO_2	0·35	0·46
	99·99	99·92

The second column is the average of sixteen analyses of the felsites of the Rooiberg series, the individual analyses being taken from Dr. Hall's Memoir on the Bushveld Complex and from papers by Professor Niggli and Dr. Lombaard (17). Dr. Lombaard kindly calculated the norm and Niggli-values of the Kopjes rock, which are as follows:—

Q	31·20	si	420
or	31·14	al	41·5
ab	27·25	fm	14
an	2·27	c	7
di $MgSiO_3$	·70	alk	37·5
di $CaSiO_3$	·81	k	·52
ap	·34	mg	·18
il	·61	c/fm	·50
hem	4·64		
Rest	·53		
	100·00		

Dr. Lombaard has also looked at the rocks and tells me that they are very like the porphyritic, fine-grained felsites of the Bushveld. It is obvious from the analysis and the nature and quantity of the felspar phenocrysts that the ground-mass must contain plagioclase felspar as well as potash felspar.

The rock taken to be a tuff from the west end of the poort through the Kopjes is seen in thin section to be a fragmental rock made entirely of pieces of the porphyry with some hydrated iron oxides staining films between fragments. The larger quartz phenocrysts are somewhat strained, but the rock is not sheared.

The Kwebe porphyry has evident petrographical resemblance to the Rooiberg felsites, and there is also similarity between the relation of the Kwebe porphyry to the Ghanzi quartzite and that of the Rooiberg felsites to the Waterberg sandstones of the Transvaal, though in general appearance the Ghanzi rocks are much more like the Matsap beds.

Amongst the rocks exposed between the floor of Ngami and the sandbult to the south there are many belonging to what Dr. Passarge called the Ngami beds (18). I was able to examine some of the outcrops, mostly in a hurried way, and I was struck by the close resemblance between the sandstones and conglomerates of the Ngami beds and those of the Waterberg System in the central Transvaal. Passarge's reasons for regarding these beds as younger than the Ghanzi beds were the presence of numerous boulders of Kwebe porphyry in the conglomerates, and also pebbles of what he believed to be Ghanzi sediments. Examination of several of the sandstone pebbles in powder did not show the presence of supposed fragments of the porphyry such as are seen in the rocks from Gagam and other places. It seemed to me that there may be a repetition here of the Rooiberg-Waterberg succession as in the Transvaal. I did not visit the Bushman valley described by Passarge. I did not see any good outcrops of the Toting diabase; Dr. du Toit wrote (19) that these rocks between one and two miles south of the old stadt of Toting and south of the river are often markedly amygdaloidal, with epidote filling many of the amygdales; he took them for lavas, and the presence of epidotic quartzite amongst them he thought indicated detrital layers amongst the lavas. He suggests that they may be of Ventersdorp age. The four specimens from near Toting examined in thin section are much altered rocks as shown by the large amount of epidote, tremolite, actinolite, and olive green biotite in them. Quartz seems to be absent from three of them; two have the felspars and epidote arranged like the felspar and augite in an ophitic dolerite. The one rock with much quartz and epidote is more like an altered sandy tuff than an igneous rock. Dr. Passarge noted the close association of the Toting diabase with the Ghanzi beds in the region north of the Ghanzi district, though not in that district. His descriptions indicated the presence of intrusive as well as of volcanic rocks in the large group of Toting diabases (20). They reminded me of the more altered parts of the basic volcanic rocks associated with the Waterberg beds in Zoutpansberg (21).

The Karroo formation in the southern Kalahari is represented by tillite, shales, and sandstones. The presence of the Dwyka tillite north of the Orange River and west of Griqualand West was first made known by specimens brought from Norokei and Eenzamheid by Dr. E. A. Nobbs in 1903 (22). The south-western limit of the present sand-veld lies for many miles on the lower part of the Karroo formation; wells and a few natural

exposures in the Kuruman and Molopo valleys and the wells at Norokei and Eenzamheid suggest that there is a very large outlier of Karroo beds underlying the sand-veld and separated from the main Karroo basin by the older rocks exposed by denudation along the Vaal-Orange drainage-line (23). On the western side the Karroo rocks extend nearly to the 24th parallel, while on the east they reach the Zambezi. A great reduction in the thickness of the Karroo sediments below the volcanic rocks takes place within the Kalahari, for two inches or less of sedimentary rock separate the basalt from the underlying gneiss on the Linyanti River and again on the Bechuanaland border west of Wankie (24), while on the south side of Ngami the rock which Dr. Passarge called the Ngami diabase (25) and aptly compared with the Loale amygdaloid, a basalt of late Karroo date, rests directly upon the uneven surface of pre-Karroo rocks. Though Passarge considered it to be intrusive at Ngami and attributed the presence of garnet in limestones there to its influence, it seemed to me to be the last remnant of the late Karroo volcanic group in that neighbourhood. The information from the sand-veld north of the Molopo is as yet very scanty. Mr. Macgregor found Karroo sediments in the south-eastern part of the Makarikari region (26), and Dr. du Toit told me that he found Karroo sandstones near Mopepe. Karroo basalt has been struck in a bore-hole at Thatchwe Pan about 30 miles north-west of Kuke Pan. The rocks on the south side of Ngami, which Dr. Passarge called the Rengaka beds (27) and placed somewhat doubtfully with his Botletle beds (Kalahari System of Maufe), are even more difficult to correlate with well-known formations than the other rocks of that region. Some of the outcrops made me spend time in trying to find Karroo fossils in them, without success, and Mr. Macgregor was evidently impressed by their resemblance to the Forest sandstone, but he could not decide the question (28).

The Karroo beds on the outskirts of the Kalahari region reach their lowest level on the Zambezi under the basalt on the north-western side of the Deka fault, which its discoverer, G. W. Lamplugh, estimated to have a throw of, probably, not less than 2000 feet (29), while Mr. Lightfoot's survey twenty years later gave an estimate of not less than 500 feet and possible 2000 feet (30) or more. The base of the Karroo beds near the Falls, then, is perhaps below sea-level. The extent of the Deka fault through the Kalahari is not known, but it has been suggested that it may be connected with the supposed fault in the Chapmans River valley over 400 miles to the south-west; the evidence of the existence of the latter fault, however, seems unsatisfactory (31). There is speculative interest in the rough parallelism of several features with trends between N.E. and E.N.E., such as the front of the Okavango delta; the rather obscure feature which Dr. Passarge called the Oas-Victoria Schwelle and looked upon as the remains

of a former hill range (32); the Deka fault; the trend of the possibly broad band of Karroo beds stretching from the Keetmanshoop district to Serowe; the main watershed of Southern Rhodesia, which extends from Marandellas in the N.E. past Plumtree into the Kalahari in the S.W., and the trend of the middle tract of pre-Karroo rocks of the Limpopo-Vaal-Orange river systems separating the great southern trough of Karroo beds—also with a N.E.–S.W. axis—from the Karroo outlier of the southern Kalahari. With exception of the delta limit and the Rhodesian watershed (33) these features are of considerable age, for they antedate the formation of the remarkably flat rock-floor on which the sands of the Kalahari have accumulated.

An attempt to trace the development of that surface takes us very far back in geological time, for in the extreme south-western part of the Kalahari a part of the surface has also been the floor of the Nama System, probably a pre-Cambrian formation, which there rests on a hilly surface of gneiss and schists. In the south-eastern part of the Kalahari the Matsap beds of the Langeberg, Korannaberg, and Molopo valley are closely folded or dip at high angles, and the two ranges mentioned are remnants of a mountain region which has been covered by Karroo deposits and again exposed by denudation. They and the smaller mountains of older rocks to the west are by far the largest hills in the Kalahari. When the deposition of the Karroo beds began in the southern Kalahari the floor probably had a more diversified surface than it has to-day, but at present there is not enough known of the pre-Karroo floor north of the Molopo to allow a similar statement to be made about it.

The development of the flat surface of solid rock, on which the sands of the Kalahari now lie, belongs to the period following the late Karroo volcanic outbursts, that is to say, to the Jurassic onwards. The removal of possibly 2000 feet of Karroo rocks, sedimentary and volcanic, from part of the country near the Wankie coalfield is an extreme measure of what may have happened over a very large region before the Kalahari sands began to accumulate. The low position of that surface above sea-level at the time the accumulation commenced can be inferred from the low grade of the Okavango, Zambezi, and the channels leading to the Orange River, but the subsequent history of the Kalahari requires discussion of the deformation or general uplift of the subcontinent as well as of the various deposits within the Kalahari itself.

REFERENCES.

(1) "Die Kalahari." Berlin, 1904.

(2) "The Geology of the North-western Part of the Wankie Coalfield," Bull. No. 4, Geol. Survey of Southern Rhodesia, 1914.

(3) "Die Kalahari," p. 344. The suggestion that the relation of the granite to the Ghanzi beds is similar to that of the granite to the Malmesbury beds at the Cape (p. 347–48) does not carry conviction; it is based on the occurrence of gneiss near the granite outcrop at Okwa and between it and the outcrop of the Ghanzi beds at Nakais 40 miles away. Dr. Passarge, however, states that the relation is not known.

(4) "Die Kalahari," p. 446.

(4a) The Dolomite occurs near Kanye.

(5) "Die Kalahari," pp. 577–81, and elsewhere.

(6) A. L. DU TOIT, "Geology of South Africa," 1926, pp. 40–41, places them in the later part of his Primitive Systems; E. KRENKEL, "Geologie Afrikas," vol. ii, p. 693, places them with the "altalgonkischen Komas System," *i.e.* in a younger group than the Swaziland-Damara Systems, though he remarks that perhaps Passarge included more than one group of rocks in his Chanseschichten. Dr. P. RANGE in "Zur Stratigraphie des Hererolandes," Monatsb. d. Deutschen Geol. Gesellschaft, Bd. lxi, 1909, No. 6, p. 298, accepts them as part of the Primary formation, but he remarks that Hermann's specimens of the sediments between Witvley and Gobabis, which Hermann correlated with the Gibeon beds (in part the equivalent of Range's Fish River beds), supported the correlation with the latter. Hermann (Monatsb. d. Deutschen Geol. Gesellschaft, 1908, p. 259) placed the Gobabis rocks in his Waterberg formation, a name taken from the Waterberg in South-West Africa. This Waterberg formation (Etjo sandstone of Schneiderhöhn and Reuning) is believed to be part of the Karroo System (A. L. du Toit, "Geology of South Africa," 1928, p. 260). So both the nomenclature and the facts may still be in some confusion. See also Fritz Jaeger and Leo Waibel, "Beitraege zur Landeskunde von Sudwestafrika," Bd. ii, p. 78. Mitt. a. d. Deutschen Schutzgebieten, Erg. hft. No. 15. Berlin, 1921.

(7) "Die Kalahari," p. 580.

(8) "Südafrika," 1908, p. 40. On p. 592 of "Die Kalahari" he suggests that the Witwatersrand beds, the Ghanzi beds, and other non-metamorphic members of the Primary formation are younger than the strongly metamorphosed.

(9) "Die Kalahari," pp. 578, 706–708, 731–32. In 1907 Professor Kalkowsky kindly let me examine the slices of Passarge's rocks in Dresden and take away chips from which they were cut. The slices from the chips brought away are in the Survey collection at Cape Town. At the time I was chiefly interested in the silicified rocks, but a piece of greywacke from the Upper Ngami beds of Rengakabucht (south side of Ngami) is amongst the rocks taken away (No. 285 of Kalkowsky's series and 1871 of the Survey slices in Cape Town), and it is very like the rocks described in the text from the Ghanzi district though coarser in grain.

(10) "Die Kalahari," ch. xx.

(11) "Die Kalahari," p. 366.

(12) Eberhard Rimann, "Geologische Karte des Khauas-Hottentottenlandes in Deutsch-Südwestafrica (Westliche Kalahari) nebst Erläuterungen." Berlin, 1913.

(13) A. L. HALL, "The Bushveld Igneous Complex," Geol. Survey Memoir, No. 28. Pretoria, 1932, pp. 435–37. R. A. DALY and G. A. F. MOLENGRAAFF, "Structural Relations of the Bushveld Igneous Complex, Transvaal," Journal of Geology, xxxii, 1904, regard the latter intrusions as belonging to a later cycle, but similarly conditioned by the nature of the magmas and the physical circumstances.

(14) Proc. Geol. Soc. S.A., xxxii, p. 48.

(15) "Die Kalahari," pp. 189, 581, 707.

(16) "Die Kalahari," p. 581.

(17) A. L. HALL, "The Bushveld Igneous Complex," 1932, p. 252. No. 9 of that series of analyses (a soda-trachyandesite) is omitted from those used for the average because it is a different type of rock. P. NIGGLI mit B. LOMBAARD "Das Bushveld als Petrographische Provinz," Schweiz. Min. Pet. Mitt., Bd. xiii, 1933, p. 112, Nos. 4, 6, 9, 10, 17, 18. B. Lombaard, "On the Differentiation and Relationships of the Rocks of the Bushveld Complex," T.G.S.S.A., xxxvii, 1934, p. 12 (*d*).

Oxide of manganese and carbon dioxide were not estimated in some of the analyses; in such cases the average figures relates only to those analyses in which the oxides concerned were estimated.

(18) "Die Kalahari," ch. vii, and pp. 581–84.

(19) He mentions the formation on p. 40 of "Geology of South Africa," 1926, but the information mentioned in the text came in letters.

(20) "Die Kalahari," pp. 190, 580.

(21) A. W. ROGERS, "Notes on the N.E. Part of the Zoutpansberg," T.G.S.S.A., xxviii, 1925, p. 40.

(22) Parl. Rep. C.G.H., G–30, 1903; Ann. Rep. Geol. Comm. for 1907, p. 13.

(23) Ann. Rep. Geol. Comm. for 1905, pp. 195–97, 249–53; Rep. for 1906, pp. 61–62, 108–21; Rep. for 1907, pp. 13–14, 76–82, 177–82. A. L. DU TOIT, "Notes on the Karroo System in the Southern Kalahari," T.G.S.S.A., xix, 1916, pp. 1–13.

(24) B. LIGHTFOOT, "The Geology of the N.W. Part of the Wankie Coalfield," Bull. No. 4, Geol. Survey of Southern Rhodesia, 1914.

(25) "Die Kalahari," ch. viii, and pp. 521, 586.

(26) A. M. MACGREGOR, "Geological Notes on a Circuit of the Great Makarikari Salt Pan," T.G.S.S.A., xxxiii, 1930, pp. 92–96.

(27) "Die Kalahari," p. 178, etc.

(28) A. M. MACGREGOR in "Report on the Rhodesia-Walvis Bay Reconnaissance Survey," Salisbury, C.S.R., 13, 1932, p. 48.

(29) G. W. LAMPLUGH, "Geology of the Zambezi Basin," Q.J.G.S., lxiii, 1907, p. 182.

(30) B. LIGHTFOOT, "Geology of the Central Part of the Wankie Coalfield," Bull. No. 15, Geol. Survey of Southern Rhodesia, 1929, p. 43.

(31) The evidence is given in Rimann, *loc. cit.*, pp. 31–32. The Kalahari-Quetsch Zone shown on pl. 34, vol. ii, of E. Krenkel's "Geologie Afrikas," 1928, is in the position of this greatly extended fault-line; the term seems to imply upthrust of the area where the Karroo sediments are now exposed; see Mr. Lightfoot's map and sections in the report referred to in the last note.

(32) "Die Kalahari," pp. 561, 588.

(33) H. B. MAUFE, "Some Problems in Rhodesian Physical Geology," S.A. Journ. Science, xxiv, 1927, pp. 31–33.

STUDIES IN DECIDUOUS FRUIT.

II.—The Effect of Time of Picking on Chemical Changes in Kelsey and Gaviota Plums in Store.

By I. Donen.

(Communicated by J. Smeath Thomas.)

(With eleven Text-figures.)

(Read March 20, 1935.)

In a previous paper (4) a description was given of experiments on the effect of time of gathering on the keeping quality of Gaviota and Kelsey plums in store. It was observed that the Kelsey plums gathered early showed a high percentage breakdown due to internal browning. All plums ultimately showed this type of browning if kept long enough in store, but its incidence was greatly retarded by late picking. Gaviota plums showed no such internal browning, but it was found that the Gaviota plums which were picked early remained firmer and showed less breakdown of tissue than the samples which were picked late.

These differences in keeping quality in store—especially in the case of the Kelsey plums—can only be ascribed to differences in chemical metabolism of the fruit. In this paper a description is given of changes in the hydrogen-ion concentration, content of acid, and sugars throughout the storage period of the plums. Similar work (6, 11, 12, 15) carried out by other investigators, mainly on apples, has not as yet led them to perceive any relation between chemical composition and keeping quality of fruit. Wallace (15), summarising from data available in 1930, states that "it does not appear that any statement of general application can be made regarding the relationship of storage qualities and any chemical constituent or group of constituents of the fruits."

These conclusions were based on observations of fruit (like the apple), which shows a slow rate of chemical change. The storage life of the Kelsey plums, however, does not exceed one hundred days, for after that period fungal attack in store was definitely noticed, and in some cases complete breakdown, due to browning, was observed even after sixty days. The storage life of the Gaviota plums is still shorter. It was thought, therefore,

that if a relation between chemical composition and keeping quality exists it should be possible to correlate it with greater ease in the case of susceptible fruit such as plums.

Expression of Results.

The method of expressing results is of great importance for correct interpretation of the actual chemical changes in store and merits a brief consideration. Haynes and Archbold (9) and their co-workers have adopted Original Fresh Weight as the basis of expression of their analytical results in order to allow for any change in concentration due to loss of water in store and thus be able to estimate absolute loss due to respiration. This method has the disadvantage of necessitating the weighing of each individual fruit before placing in store and after removal from it. In this investigation the lack of necessary facilities made the adoption of this method impossible. The alternative method of weighing out the whole sample and taking mean weights was found to give scattered results due to individual variations which made the method quite unreliable.

The best method of expressing results would be on the basis of some chemical property known to be unaffected by time in store. Total ash would be such an ideal quantity, but the estimation of it is tedious and difficult. It was, therefore, decided to express results per unit of total nitrogen. Although changes in the composition of the nitrogen fractions present in plant tissue have been observed by various researchers, no actual loss in total nitrogen is found under conditions of storage. Therefore changes in total nitrogen can with considerable assurance be taken as being due to loss of water only. In addition, expression of results on this basis assumes a peculiar significance in the light of work done by Archbold and Haynes. These workers have found a correlation between nitrogen content and rate of respiration (1), and suggest that the nitrogen content is a measure of the protoplasmic content and that the rate of respiration is determined by the protoplasmic surface (9). It can, therefore, be argued that determination of loss per unit of total nitrogen is a truer expression of respiratory activity than rate of loss of respirable material per unit of weight.

Experimental Methods.

Complete details of the method of gathering and sampling in the orchard have been given in the previous paper (4). A brief summary is given here for the sake of clarity. Samples were chosen from four orchards situated in localities varying greatly in climatic conditions. Four pickings were made. As the rate of ripening of the plums on the same trees varied considerably it was possible to select samples in various stages of maturity

although gathered on the same day. The stages selected were as follows: Stage I, under-ripe plums, too green for export; Stage II, export plums; Stage IIA, plums suitable for export but ripening late in the season; Stage III, fruit in an over-ripe condition.

The plums were then placed in a commercial cold store at 34° – 36° F. and samples of twenty fruits were withdrawn at regular intervals and analysed. They were cut up finely by hand and well mixed. Samples were then taken for determination of Nitrogen and Alcohol Insoluble Residue. The rest of the sample was pressed without previously freezing the pulp. The juice was immediately centrifuged and aliquot samples taken for acidity and sugar determinations. The juice was preserved by heating at 70° C. for one hour and then adding a crystal of thymol.

The analysis consisted of the following estimations:—

(I.) *Sugars.*—20 c.c. juice were used for each estimation. The method followed was as described by Archbold (3). The juice was neutralised with N/10NaOH, cleared with basic lead acetate and sodium hydrogen phosphate, and the Fehling's value was determined by the method of Lane and Eynon (10) using Methylene Blue as indicator. Fructose and glucose were obtained by calculation after determining the iodine value of an aliquot portion of the sample. Sucrose was obtained by difference after inversion with hydrochloric acid as recommended by Hinton and Macara (7) and determining the Fehling's value of the inverted solution.

(II.) *Acidity.*—10 c.c. juice was titrated with N/10 NaOH using phenolphthalein as indicator. A sharp end-point can be obtained by diluting to 400 c.c. before titration.

(III.) *Alcohol Insoluble Residue* was determined by allowing 100 gms. of sample to stand overnight with about 150 c.c. alcohol and then extracting with fresh alcohol for twenty-four hours in a Sohxlet extractor.

(IV.) *Specific Gravity* of the juice was determined by means of a Westphal balance or by using a specific gravity bottle.

(V.) *Total Nitrogen.*—Samples of plum pulp previously dried at 50° C. for about seventy-two hours were used (2). The estimations were carried out, using the modified Kjeldhal method to include nitrates. It was found that consistent results agreeing well within 3 per cent. could be obtained if the dried tissue was well mixed and finely ground.

(VI.) *pH Values* were determined on a sample of centrifuged juice using a potentiometer with a Quinhydrone and N/10 Calomel electrodes. It was found that centrifuging the juice had no effect on the pH value. All determinations were made immediately, as it was found that, although the juice was preserved with thymol, the pH values changed on standing. H-ion concentrations were then calculated from the pH values.

All determinations on the juice were calculated back to the fresh weight by the formula

$$W = \frac{(100 - R)C}{S} \text{gms.},$$

where W = Weight per 100 gms. of fresh weight
R = Alcohol insoluble residue.
S = Specific gravity of juice.
C = Concentration of the estimated quantity of sugar or acid per 100 c.c. of juice.

This formula is based on the assumption that fresh weight consists of juice and alcohol insoluble residue. The accuracy of this formula is discussed by Evans (5) and by Haynes (8).

The Course of Chemical Change.

A complete analysis of a representative sample of each picking was carried out before the plums were placed in store. The Kelsey plums were analysed again after eighty days in store and losses due to respiration were thus estimated. At the same time regular analyses were carried out weekly on samples of four pickings of Kelsey and Gaviota plums taken from the same orchard. The actual course of chemical change in store was thus traced over a period of about one hundred days.

When considering the data given in Tables I–IX it is essential to emphasise the difference between Kelsey and Gaviota plums. The former plums showed considerable differences in chemical composition connected with delayed picking. The acidity, nitrogen content, and H-ion concentration diminished considerably with each successive stage. The sugar content increased with delay in time of gathering. The differences in the initial chemical composition of various pickings of Gaviota plums were not so marked. The nitrogen and acid content did not vary to any considerable degree, although late picked samples showed an increase in total sugar. When picked, both the Kelsey and Gaviota plums were free of starch, the hydrolysis of the latter being completed during the ripening process on the tree.

TABLE I.

KELSEY PLUMS. STAGE I. DATE OF GATHERING, 29/1/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. N/10 NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·0992	1·68	1·041	3·42	3·58	154·4	3·03	4·52	7·55	5·12	12·67
11	·0948	1·84	1·050	3·48	3·23	144·5	3·25	4·42	7·67	3·56	11·23
20	·0963	1·82	1·051	3·48	3·21	123·6	3·21	3·85	7·06	3·54	10·60
31	·0962	1·82	1·057	3·64	2·21	91·5	3·10	3·28	6·38	3·41	9·79
42	·1048	1·65	1·057	3·74	1·60	66·9	2·53	2·72	5·25	4·33	9·58
49	·1062	1·95	1·041	3·80	1·40	52·3	2·56	2·75	5·31	4·77	10·08
56	·1023	1·65	1·058	3·97	0·98	45·4	2·50	2·85	5·35	4·64	9·99
63	·1050	1·68	1·056	4·04	0·80	38·1	2·42	2·88	5·30	4·57	9·87
71	·1148	1·52	1·056	4·09	0·66	34·1	2·27	2·42	4·69	4·58	9·27
79	·1122	1·59	1·054	4·26	0·45	28·4	2·26	2·91	5·17	4·21	9·38
86	·1046	1·84	1·055	4·26	0·49	25·4	2·44	3·39	5·83	3·97	9·80
93	·1121	1·69	1·056	4·31	0·40	21·0	2·36	3·32	5·68	3·28	8·96
103	·1124	1·76	1·056	4·52	0·25	15·8	2·48	3·54	6·02	2·97	8·99

TABLE II.

KELSEY PLUMS. STAGE II. DATE OF GATHERING, 29/1/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. N/10 NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·0996	1·68	1·060	3·47	3·11	136·3	3·27	4·28	7·55	5·38	12·93
11	·0928	1·81	1·060	3·52	3·00	141·0	3·37	4·70	8·07	3·60	11·67
20	·0958	1·95	1·050	3·55	2·76	122·3	3·27	3·84	7·11	3·86	10·97
31	·0937	1·77	1·057	3·69	2·04	91·4	3·30	2·83	6·13	4·32	10·45
42	·0958	1·84	1·052	3·78	1·61	68·2	2·82	2·74	5·56	5·51	11·06
49	·0985	1·77	1·057	3·78	1·58	56·0	3·42	2·12	5·54	5·50	11·04
56	·0932	1·80	1·056	3·98	1·04	55·2	2·64	3·24	5·88	6·93	12·81
63	·1041	1·60	1·046	4·02	0·87	37·1	2·46	2·83	5·29	5·52	10·81
70	·1089	1·54	1·055	4·10	0·68	32·7	2·52	2·62	5·14	4·40	9·54
78	·1015	1·78	1·061	4·27	0·48	30·7	2·46	3·08	5·54	5·47	11·01

TABLE III.

KELSEY PLUMS. STAGE IIA. DATE OF GATHERING, 8/2/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. N/10 NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·0983	1·75	1·060	3·51	2·91	132·0	3·44	4·05	7·49	4·03	11·52
10	·1020	1·62	1·061	3·55	2·54	113·4	3·39	3·90	7·29	4·08	11·37
20	·1043	1·54	1·064	3·65	1·99	83·8	3·52	3·16	6·68	4·00	10·68
31	·1115	1·64	1·064	3·70	1·72	67·2	2·83	2·62	5·45	4·37	9·82
39	·1096	1·67	1·067	3·83	1·25	51·4	2·50	2·70	5·20	5·23	10·43
46	·1051	1·69	1·041	3·97	0·97	50·6	2·48	2·75	5·23	5·64	10·87
54	·1159	1·61	1·066	4·10	0·63	38·5	1·99	2·13	4·12	5·61	9·73
61	·1104	1·69	1·065	4·18	0·56	35·8	2·21	2·17	4·38	5·97	10·35
69	·1081	1·81	1·065	4·34	0·39	29·8	2·21	2·34	4·55	6·11	10·66
81	·1067	1·78	1·063	4·38	0·36	24·9	2·15	2·44	4·59	6·18	10·77
91	·1118	1·61	1·065	4·41	0·32	21·7	2·06	2·62	4·68	5·41	10·09
101	·1038	1·77	1·065	4·55	0·25	18·9	2·20	2·80	5·00	6·06	11·06

TABLE IV.

KELSEY PLUMS. STAGE III. OVER-RIPE. DATE OF GATHERING, 8/2/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. N/10 NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·09131	1·76	1·052	3·64	2·31	132·0	3·46	4·71	8·17	5·16	13·33
10	·09883	1·61	1·064	3·61	2·21	108·6	3·14	3·52	6·66	6·41	13·07
20	·09625	1·65	1·071	3·69	1·97	99·0	3·10	3·05	6·15	6·22	12·37
31	·09102	2·12	1·071	3·76	1·75	79·7	2·99	2·79	5·78	7·32	13·10
39	·0989	1·65	1·069	3·85	1·32	53·5	2·91	2·57	5·48	7·39	12·87
46	·0980	1·78	1·069	4·03	0·87	50·2	2·54	2·62	5·16	7·19	12·35
54	·1050	1·62	1·069	4·21	0·54	38·0	2·32	2·42	4·74	7·08	11·82
61	·0963	1·65	1·066	4·26	0·52	35·2	2·66	2·51	5·17	7·85	13·02
69	·1019	1·61	1·069	4·39	0·37	28·0	2·23	2·69	4·92	6·94	11·85
81	·1089	1·69	1·070	4·39	0·35	23·8	2·14	2·44	4·58	6·79	11·37
91	·1066	1·92	1·071	4·42	0·34	23·0	2·06	2·33	4·39	7·26	11·65
101	·1209	1·62	1·072	4·45	0·27	17·7	2·00	2·63	4·63	5·65	10·28

TABLE V.

GAVIOTA PLUMS. UNDER-RIPE. STAGE I. DATE OF GATHERING, 8/1/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. N/10 NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·1211	1·41	1·047	3·18	5·09	189·0	2·29	2·21	4·50	3·38	7·88
9	·1180	1·45	1·049	3·26	4·33	149·7	2·58	2·38	4·96	4·18	9·14
17	·1163	1·43	1·051	3·37	3·45	129·3	2·39	2·98	5·37	4·33	9·70
23	·1170	1·43	1·045	3·35	3·59	118·7	2·60	2·80	5·40	3·52	9·02
33	·1180	1·44	1·040	3·43	2·99	108·8	2·49	3·12	5·61	3·28	8·89
43	·1145	1·38	1·045	3·50	2·61	99·0	2·21	2·78	4·99	2·82	7·81
57	·1238	1·19	1·045	3·80	1·16	46·7	1·58	2·71	4·29	2·88	7·17

TABLE VI.

GAVIOTA PLUMS. STAGE II. DATE OF GATHERING, 8/1/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. N/10 NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·1087	1·47	1·046	3·26	4·82	201·0	2·84	2·29	5·13	3·87	9·00
9	·1329	1·33	1·048	3·33	3·36	122·6	2·35	2·41	4·76	3·80	8·56
17	·1219	1·44	1·047	3·44	2·81	113·7	2·21	3·16	5·37	4·16	9·53
23	·1191	1·35	1·048	3·42	3·03	110·0	2·41	3·24	5·65	3·81	9·46
33	·1180	1·28	1·047	3·48	2·60	100·2	2·59	2·86	5·45	2·88	8·35
43	·1235	1·22	1·047	3·47	2·56	93·5	1·90	2·77	4·67	2·24	6·91
57	·1212	1·31	1·047	3·78	1·28	46·9	1·84	2·33	4·17	2·85	7·02

TABLE VII.

GAVIOTA PLUMS. STAGE IIA. DATE OF GATHERING, 16/1/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. $N/10$ NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·1272	1·22	1·054	3·22	4·37	171·0	2·49	2·03	4·52	3·46	7·98
8	·1240	1·25	1·056	3·38	3·10	124·5	2·07	2·70	4·77	3·92	8·69
16	·1177	1·32	1·050	3·40	3·18	117·9	2·27	2·89	5·16	3·49	8·65
26	·1314	1·18	1·051	3·46	2·49	96·8	2·13	2·52	4·65	3·35	8·00
33	·1250	1·15	1·054	3·56	2·03	95·8	2·16	2·49	4·65	3·16	7·81
44	·1263	1·22	1·053	3·49	2·42	83·8	2·17	2·39	4·56	2·86	7·42
53	·1335	1·20	1·054	3·57	1·86	57·7	1·68	2·09	3·77	3·23	7·00
63	·1319	1·07	1·052	3·66	1·56	46·8	1·77	2·14	3·91	3·32	7·23
70	·1283	1·17	1·052	3·81	1·14	43·3	1·86	2·20	4·06	3·07	7·13

TABLE VIII.

GAVIOTA PLUMS. STAGE III. DATE OF GATHERING, 16/1/34.

All results are expressed in gms. per unit total nitrogen.

Days in store.	Total nitrogen in 100 gm. fr. wt.	Alcohol insol. residue.	Sp. gr. of juice.	pH of juice.	H-ion gm. equiv. $\times 10^5$.	Acid c.c. $N/10$ NaOH.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.
0	·1261	1·27	1·054	3·27	3·98	164·0	2·36	2·31	4·67	3·70	8·37
8	·1185	1·35	1·059	3·43	2·93	129·0	2·20	3·04	5·24	3·95	9·19
16	·1235	1·30	1·055	3·53	2·24	96·4	2·13	2·95	5·08	3·54	8·62
26	·1341	1·09	1·054	3·58	1·83	87·1	2·44	2·48	4·92	3·33	8·25
33	·1240	1·17	1·055	3·67	1·62	82·5	2·15	2·71	4·86	3·36	8·22
44	·1212	1·19	1·054	3·52	2·33	82·8	2·11	2·67	4·78	3·62	8·40
53	·1230	1·21	1·053	3·72	1·44	53·2	2·15	1·81	3·96	4·46	8·42
63	·1256	1·12	1·052	3·78	1·23	40·0	1·84	2·28	4·12	3·82	7·94
70	·1223	1·21	1·050	3·89	0·98	37·8	1·96	2·25	4·21	3·68	7·89

In store the behaviour of the plums was entirely different. Thus the Kelsey plums, as mentioned before, soon began to show internal browning accompanied by collapse of tissue. This was most severe in the samples designated as Stage I, *i.e.* those picked in an immature condition. Plums of the second picking behaved in a similar manner to those of Stage I.

Plums picked late showed hardly any browning. The Gaviota plums showed no such physiological disturbance, and all samples behaved in the same way in that after a similar period of time in store all turned "bladdery."

It would, therefore, be expected that if the physiological disturbance in the case of the Kelsey plums is due to their chemical metabolism, the changes in composition of plums of Stages I and III should be widely different. No such differences should be observed in corresponding stages of the Gaviota plums.

Changes in Sugar Content of Gaviota Plums.

Although twenty plums were used for each sample analysed, the scatter of the points in the curves showing the changes in store was considerable. Even more frequent analyses than those carried out with the Gaviota plums are apparently necessary to trace the rapid changes in the chemical composition. There were, however, definite changes common to all four pickings, showing significant changes in the loss of both sugar and acid per unit of nitrogen. Such changes were assumed to be significant when the change in concentration in any period of time was greater or less than twice the change in concentration during a period immediately preceding it.

A slight increase in total sugar was observed in all samples during the first nine days in store. That period was slightly longer for the first two pickings than for Stages IIa and III. It is difficult to account for that rise in sugar, as qualitative tests with iodine on the alcohol insoluble residue showed no presence of starch at the time the fruit was gathered. The increase was greatest in the first picking, and was accompanied by a slight rise in sucrose and reducing sugars. Fructose was the sugar accumulated during that time, glucose remaining constant as in Stage I, or slowly diminishing, apparently by conversion to fructose, as in Stages II, IIa, and III. Thus there was apparently no consumption of sugar during that period. The loss in acid content was considerable, however, being about 20 per cent. of the total acid in Stages I and III and even higher in the other two stages (see figs. 1, 2, and 7).

The second period lasted for all pickings till about forty-four days in store. It was characterised by a slow and uniform acid consumption, the rate of loss being about four times as slow as that during the previous period. The rate of total sugar loss was almost uniform, being higher in the first two pickings than in the last two.

In the first picking reducing sugars accumulated till about thirty-three days in store and then steadily diminished. The reducing sugars in the other three pickings decreased throughout this second period, showing

that the rate of sugar consumption was greater than the rate of inversion of sucrose.

The loss of reducing sugars in the first picking was made up evenly of fructose and glucose. The consumption of fructose relative to glucose slowly increased in the latter pickings and loss of fructose was double that of glucose in the fourth picking.

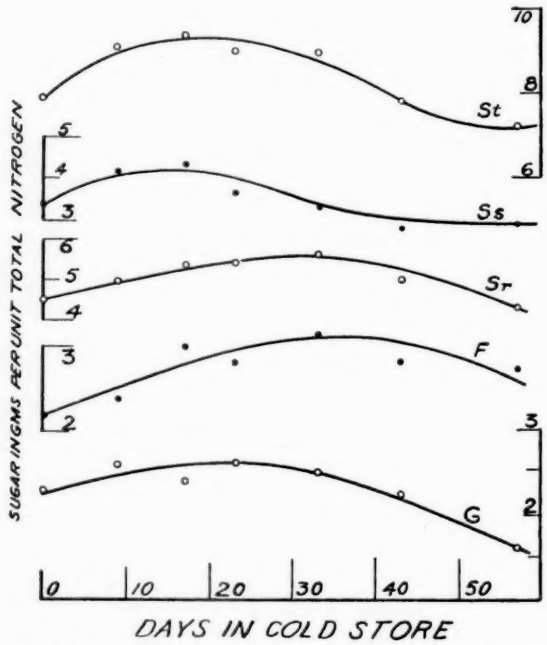

FIG. 1.—Changes in the sugar content of Gaviota plums (first picking) with time in store. St = total sugar; Ss = sucrose; Sr = reducing sugars; F = fructose; G = glucose.

The beginning of the third period coincided with the appearance of considerable softening and bladderiness of the plums in store. In the case of the first two stages this period was kept under observation for fourteen days in store, and the last two stages for twenty-six days. The rate of loss of total sugar decreased considerably. Thus in the third picking it fell to one-third of its previous value. Inversion of sucrose apparently ceased completely in the first and third pickings. In Stages II and IIA a slight increase in sucrose was actually observed, indicating a possible reversal of equilibrium. The loss of sugar due to respiration in Stages I and IIA was entirely due to glucose, while in Stages II and IIA the gain in

sucrose was equal to the loss of fructose. This change in the sugar equilibrium was accompanied by an increased consumption of acid, as can be seen in fig. 7.

The changes in the Gaviota plums kept in store at 34° – 36° F. could therefore be summarised as follows: There was a rapid loss of acid during

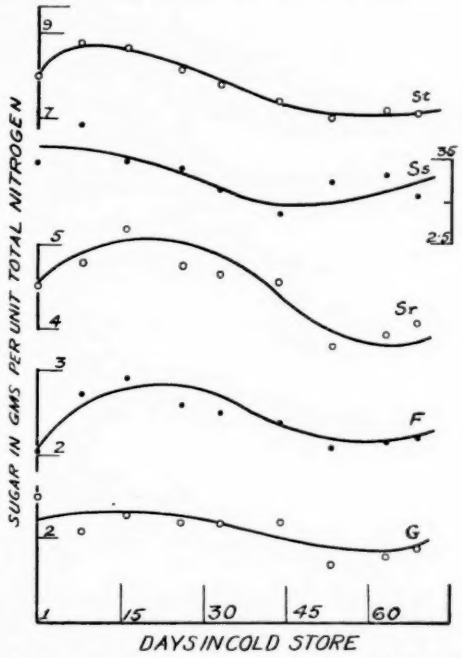

FIG. 2.—Changes in the sugar content of Gaviota plums (third picking) with time in store. St = total sugar; Ss = sucrose; Sr = reducing sugars; F = fructose; G = glucose.

the first ten days, and very little or no consumption of sugar. After that reducing sugar slowly decreased, fructose mainly being lost. Acid was then lost at a slower rate until about forty-four days in store, when a sudden increase in acid consumption took place, inversion of sucrose stopped, and loss of sugar became *nil* in some pickings. This apparent change in sugar equilibrium was correlated with the beginning of breakdown in the plums. No significant differences in the rate of respiration (as measured by loss of sugar and acid) in the different pickings were observed. This suggested that actual respiratory activity was not responsible for the differences in percentage breakdown noticed in the various pickings of Gaviota plums. Actual firmness of the fruit when placed in store might therefore be a

determining factor in the storage life of these plums. Such firmness is connected with the amount of cell-wall material in the fruit. It should be noticed in this connection that the alcohol insoluble residue per 100 gms. Fresh Weight decreased with delay in picking, and that for the three orchards examined Gaviota plums that were picked early showed less breakdown in store than plums gathered late.

Changes in Sugar Content of Kelsey Plums.

Total sugar fell continuously throughout the storage life of the Kelsey

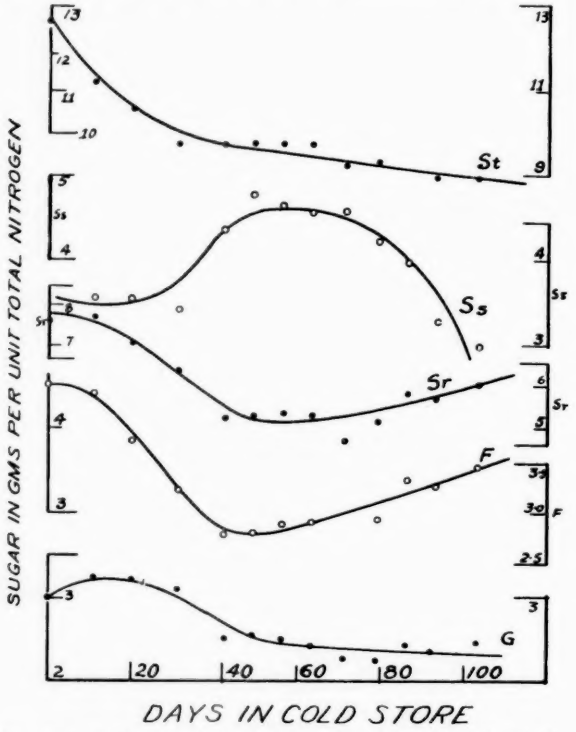

Fig. 3.—Changes in the sugar content of Kelsey plums (first picking) with time in store. St = total sugar; Ss = sucrose; Sr = reducing sugars; F = fructose; G = glucose.

plums. In Stages IIa and III the consumption of total sugar was approximately uniform over the whole period of one hundred days. Mean loss of sugar per day over this period was ·011 gm. and ·0243 gm. respectively.

In Stages I and II the rate of loss of sugar diminished rapidly and reached a minimum value after about forty-two days in store. This change in the rate of loss of sugar in Stages I and II is in striking contrast to Stages

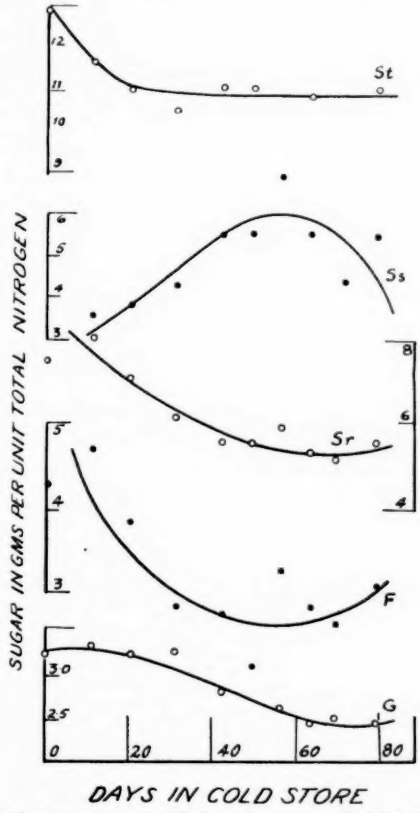

FIG. 4.—Changes in the sugar content of Kelsey plums (second picking) with time in store. St = total sugar; Ss = sucrose; Sr = reducing sugars; F = fructose; G = glucose.

IIA and III. Thus during the period 0–42 days the mean loss of sugar in the first and second pickings was ·093 gm. and ·0446 gm. per day. After forty-two days in store the rate of loss of sugar in the first stage fell to the mean value of ·0111 gm. per day and remained practically constant during the rest of the observed storage period. In plums of Stage II loss of sugar during that period was practically *nil*.

The changes in the sucrose content of the Kelsey plums were strikingly

different from those observed in the Gaviota plums and indicate a difference in the metabolic changes undergone by the fruit while in store. It should be added that the chemical changes in store of the Gaviota plums were

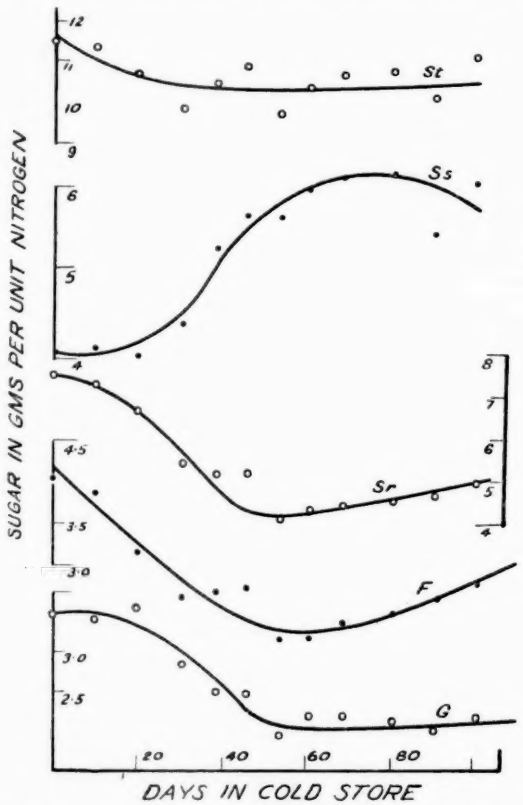

FIG. 5.—Changes in the sugar content of Kelsey plums (third picking) with time in store. St = total sugar; Ss = sucrose; Sr = reducing sugars; F = fructose; G = glucose.

generally similar to those in apples as found and described by Archbold (3). This was definitely not the case with the Kelsey plums.

It would seem as if the mechanism for inversion of sucrose was definitely inhibited in the beginning of the storage life of these plums. Thus there was a definite rise in the sucrose concentration in all pickings which proceeded at a steadily increasing rate for about forty to fifty days in store. This increase was definitely at the expense of the reducing sugars, for the

loss of the latter during the period exceeded the amount consumed in respiration. The loss of reducing sugars in the first picking was evenly divided between glucose and fructose. In the other three pickings the decrease in fructose was much greater than that of glucose, and it would

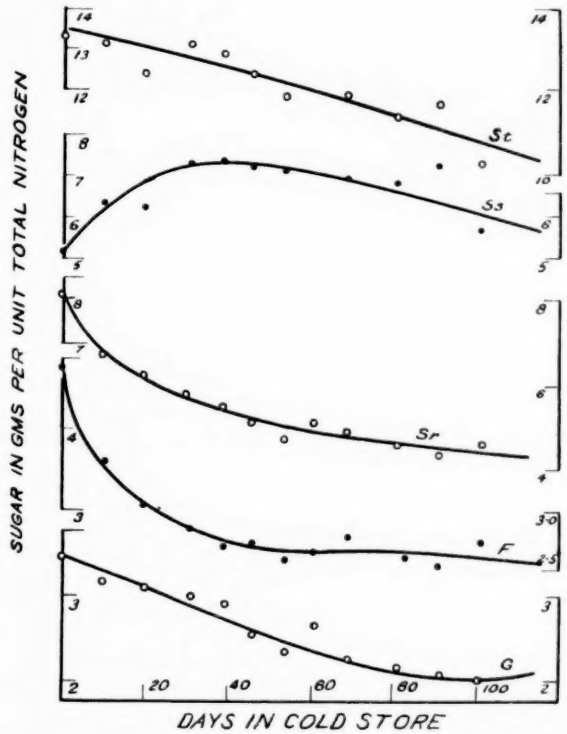

FIG. 6.—Changes in the sugar content of Kelsey plums (fourth picking) with time in store. St = total sugar; Ss = sucrose; Sr = reducing sugars; F = fructose; G = glucose.

seem as if it was the fructose that principally changed into sucrose. It is interesting to note that when the reversal in sugar equilibrium of the Gaviota plums was observed after about forty-two days in store it was also principally fructose that changed into sucrose.

After forty-two days in store Kelsey plums of the first and second pickings began to show browning of the flesh around the pit. The first signs of this physiological disturbance in plums of Stages IIA and III were observed only after fifty-four days in store, and it increased at a much slower rate

than in the plums of the first two pickings. Simultaneously with this onset of progressive internal breakdown of the plums, inversion of sucrose was noted in all pickings. In plums of Stage I the rate of sucrose inversion increased rapidly and soon exceeded the amount of sugar respired. Glucose was apparently preferentially oxidised during that period, since fructose was the sugar which accumulated. All excess glucose formed by inversion of sucrose and not respired was changed into fructose. This conversion of glucose into fructose was also noticed in the remaining three pickings during the period of sucrose inversion. In the third and fourth pickings, however, the amount of sugar respired was slightly greater than the amount of sucrose inverted, glucose being the extra sugar respired.

TABLE IX.

CHEMICAL COMPOSITION OF KELSEY PLUMS ON STORING AND AFTER 80 DAYS IN STORE.

Results are expressed in gms. per 100 c.c. juice.

Sample.	Nitrogen in 100 gm. fr. wt.	Acidity c.c. N/10.	pH.	H-ion gm. equiv. × 10.	Alcohol insoluble residue.	Glucose.	Fructose.	Reducing sugar.	Sucrose.	Total sugar.	Per cent. breakdown after 80 days in store.
A. I	·0992	162·8	3·42	3·77	1·75	3·19	4·76	7·95	5·40	13·35	100
A. II	·0996	147·8	3·52	3·00	1·82	3·55	4·64	8·19	5·83	14·02	100
A. IIA	·0983	140·2	3·51	3·09	1·72	3·64	4·29	7·93	4·27	12·20	50
A. III	·0913	129·2	3·64	2·27	1·72	3·38	4·61	7·99	5·05	13·04	50
B. I	·1170	157·8	3·53	2·97	1·55	1·98	3·09	5·07	5·00	10·07	100
B. II	·0986	141·0	3·62	2·38	1·56	2·65	3·50	6·15	5·93	12·08	100
B. III	·0879	149·5	3·63	2·34	1·57	2·75	3·11	5·86	6·46	12·33	69
C. I	·1025	187·5	3·42	3·74	1·86	2·85	3·59	6·44	3·29	9·73	100
C. II	·0990	177·2	3·49	3·22	1·68	2·95	3·81	6·76	3·91	10·67	100
C. III	·0945	156·3	3·44	3·59	1·68	3·78	1·61	5·39	6·40	11·79	26
D. IIA	·1136	120·0	3·64	2·23	1·59	3·00	3·45	6·45	6·29	12·70	32
After 80 Days in Store.											
A. I	·1122	30·4	4·26	0·55	1·58	2·42	3·12	5·54	4·50	10·04	
A. II	·1015	33·1	4·27	0·52	1·92	2·65	3·33	5·98	5·90	11·88	
A. IIA	·1067	26·5	4·38	0·39	1·78	2·29	2·60	4·89	6·47	11·36	
A. III	·1089	23·7	4·39	0·32	1·69	2·13	2·43	4·56	6·76	11·32	
B. I	·1316	42·0	..	..	1·51	2·06	3·00	5·06	3·90	8·96	
B. II	·1206	21·6	4·14	0·59	1·49	2·28	2·49	4·77	4·32	9·09	
B. III	·1052	49·9	3·89	1·19	..	2·55	2·94	5·49	6·64	12·13	
C. I	·1159	38·3	4·03	0·82	1·70	2·31	3·02	5·33	3·93	9·26	
C. II	·1036	37·3	4·06	0·87	1·61	2·72	3·61	6·33	4·75	11·08	
C. III	·0972	27·0	4·29	0·52	1·57	2·63	3·34	5·97	6·72	12·69	
D. IIA	·1246	30·0	4·23	0·55	1·75	2·23	2·74	4·97	7·03	12·00	

The reversal of sugar equilibrium in Stages I and II began simultaneously with the fall of the rate of sugar consumption. As the first appearance of internal browning was observed at the same time, this period in the metabolism of the plums seems of great significance. From Table IX it will be seen that after eighty days in store samples of plums that showed good keeping quality showed high sucrose content. This is more noticeable when sucrose is expressed as percentage of total sugar. Then it will be seen that Stage IIA and Stage III, orchard A., show a much higher increase in sucrose than Stages I and II. Samples B. I and B. II show a decrease in sucrose percentage, while B. III, which kept comparatively well in cold store, shows a slight increase. D. IIA also shows an increase in sucrose content, while C. III has a much higher sucrose percentage on picking and after eighty days in store than C. I and C. II, which exhibited a high percentage of browning. It can therefore be concluded that in all samples of plums that kept well in store the rate of sucrose inversion was much slower than in those that exhibited high breakdown and that the chemical metabolism in all those plums was the same as that described above. It seems, therefore, that the change in equilibrium of the sugars in the Kelsey plums is intimately connected with their internal breakdown. The fall in the rate of loss of sugar observed at this stage is possibly an indication of complete change of the character of respiration. There is no evidence as yet as to the nature of the change, but the progressive breakdown of protein in apples kept in store and described by Pearsall and Pilling might be significant in this connection (12). Preliminary work has shown that such breakdown of protein does occur in Kelsey plums. Further investigation of this problem is proceeding.

Acid Changes in the Kelsey and Gaviota Plums.

The differences between the chemical changes of the sugars in the Gaviota and Kelsey plums have already been stressed. Figs. 7 and 8 indicate that marked differences exist also in the acid changes of these two varieties. This is best seen on comparing these curves with those in fig. 11. The logarithmic decline of acidity for Gaviota plums yields curves similar to those of acid/time as shown in fig. 7. The logarithmic decline of acidity in the Kelsey plums, however, follows a straight line relation.

It has been mentioned before that acid is rapidly depleted in the Gaviota plums during the first ten days or so in store when sugar consumption is low. As much as 39 per cent. of the total acid was lost in plums of the second picking during that period. As rate of sugar consumption increased the rate of loss of acid decreased till about forty-two days in store. In all pickings a sudden rise in the rate of acid loss was then observed and was correlated with a reversal of the carbohydrate equilibrium in the plums and

a diminution of sugar consumption. The increase in the rate of loss of acid was not sustained, however, and after a further twenty-five days it was found that in Stages IIA and III the rate of loss returned to its original level.

In the first and second pickings of the Kelsey plums the rate of acid

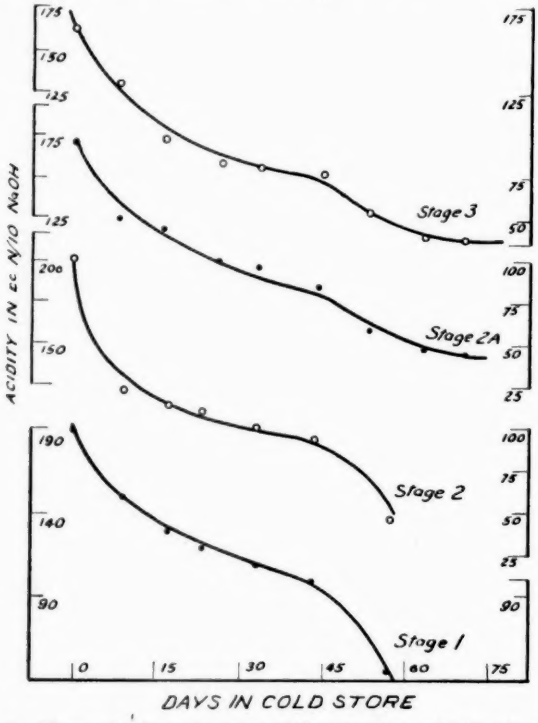

FIG. 7.—Changes in the acid content of Gaviota plums with time in store.

loss increased and reached a maximum after about thirty-one days in store. The rate of loss then slowly diminished and kept at an approximately constant value throughout the rest of the observed storage life. Samples IIA and III showed no increase to a maximum value of acid loss. The amount of acid consumed per day steadily diminished throughout the storage period. As can be seen from fig. 8 the graphs of acidity for the last two pickings tend to flatten out after about ninety days in store, *i.e.* the acid content diminished very slowly and apparently reached some constant minimum value. The changes in the rate of acid consumption just

described were calculated from the graphs of acidity by the method of midordinates.

It should be noticed that, unlike the Gaviota plums, there was no increase in amount of acid loss per day with the appearance of breakdown in the plums and onset of the disturbance in the carbohydrate equilibrium. In

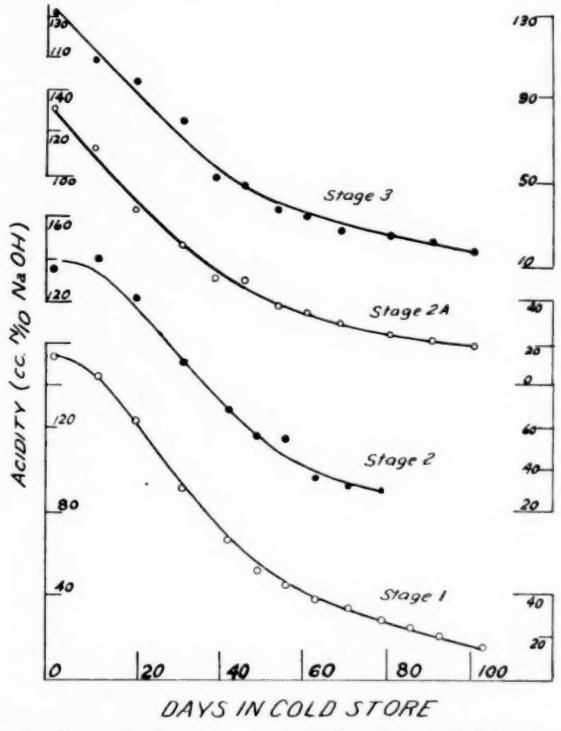

FIG. 8.—Changes in the acid content of Kelsey plums with time in store.

Stages IIA and III there was actually a definite slowing down of rate of acid consumption at that particular time. The mean acid loss per day in the first and second pickings was 2·08 and 1·78 c.c. N/10 per day prior to the first appearance of internal browning. Stages IIA and III lost acid at the rate of 1·74 c.c. per day until the fifty-fourth day in store when beginning of browning was observed in these plums. For the rest of the observed storage period the mean loss of acid was respectively 0·84, 1·01, 0·42, 0·43 c.c. N/10 per unit nitrogen per day.

Thus a diminution not only in sugar consumption but also in acid loss was found to coincide with appearance of breakdown in the Kelsey plums.

Changes in H-ion Concentration.

The changes in H-ion concentration of the plums, which were observed throughout the storage period, still remain to be discussed. Plagge and

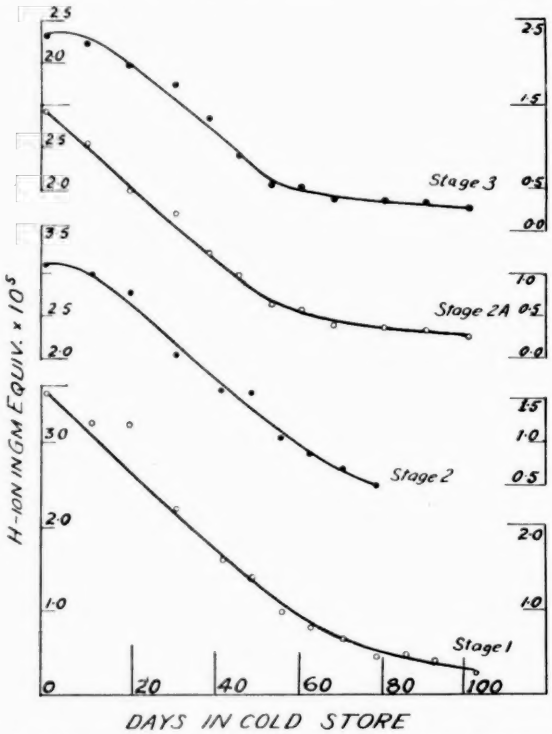

Fig. 9.—Changes in the H-ion concentration of the Kelsey plums with time in store.

Gerhardt (13) have suggested that there is an intimate balance between H-ion concentration and keeping quality of Grimes and Jonathan apples. Reyneke and Du Toit (14) have argued that high degree of dissociation of the acid raises the availability of the acid for respiration in store and favours better keeping quality of the fruit. They maintain that it is the dissociated acid that is respired and not the undissociated acid as suggested by Haynes and Archbold (9).

The similarity of the curves of acidity and H-ion per unit of nitrogen in the plums, as seen in figs. 8 and 9, definitely indicates than an intimate relationship exists between the changes of these two constituents. This is confirmed when changes of acid are plotted against those of H-ion concentration. The relationship is found to be linear. A more closely fitting

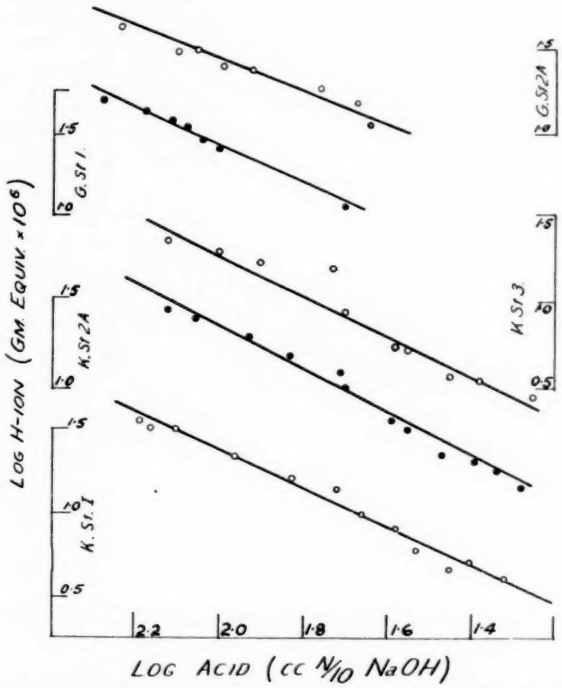

FIG. 10.—The logarithmic relation between the changes of acid and H-ion concentration in the Kelsey and Gaviota plums.

straight line can be obtained by plotting the logarithms of acid and H-ion concentration (fig. 10). The series of parallel straight lines obtained for the H-ion/acid relationship in the different pickings of both Kelsey and Gaviota plums suggests that the degree of dissociation and equilibrium constant of the acid is not affected by variety or the time of picking, and that this H-ion/acid equilibrium is not disturbed by the onset of breakdown in store.

The most important feature in connection with H-ion changes is the fact that rate of loss of H-ion became very small in all stages of the Kelsey

plums after reaching a value of $0{\cdot}5 \times 10^{-5}$ gram-equivalents. For the Gaviota plums this value is $2{\cdot}5 \times 10^{-5}$ gram-equivalents. It is perhaps significant that this minimum value in the good samples of the Kelsey plums was reached much earlier than in the samples highly prone to breakdown. In the Gaviota plums, which did not show marked differences in keeping quality, the minimum value was reached in all samples after a similar period in store.

Chemical Changes and Internal Breakdown.

Several investigators have stressed the bearing of acid changes upon internal breakdown. Thus, Plagge and Gerhardt (13) have found that loss of acid is inversely related to the amount of breakdown in apples. Haynes and Archbold state that acidity can be used at ordinary temperatures as a measure of storage life (9). From various published observations they infer that in the process of respiration sugar is oxidised with formation of acid and that acid loss is therefore controlled by the amount of acid formed by oxidation of sugars. It follows that a low rate of respiration of sugars will be accompanied by a high loss of acid. This leads to the further inference that as good keeping quality depends on the constant supply of acid from oxidation of sugars to keep up acid equilibrium, beginning of breakdown should be correlated with an "overdraft" on the stored acid and an exhaustion of sugars or some sugar which is preferentially oxidised. Many of the sets of analyses of apples published suggest that this essential constituent is sucrose, for exhaustion of the supply of sucrose has been found in many cases to coincide with the end of the apple's storage life. Archbold and Haynes conclude, therefore, that the respiratory mechanism of apples is especially fitted to deal with sucrose, and that a possible cause of breakdown may be an insufficient supply of cane sugar in the process of inversion (9).

The observations in this investigation definitely indicate an increase in loss of acid at the moment when rate of loss of sugar diminishes. This was most noticeable in the Gaviota plums, where a high acid loss was found during the first ten days when sugars were increasing. There was also a rise in acid consumption on about the forty-fourth day in store when onset of bladderiness was observed and sugar consumption definitely decreased. In the Kelsey plums the rapid fall in the rate of sugar consumption observed in Stages I and II was accompanied by an increase in the rate of acid loss. This was not observed in Stages IIA and III, where rate of loss of sugar remained uniform. This therefore confirms the inference of Haynes and Archbold that observed acid loss is high when loss of sugar is low.

The total consumption of sugar during the storage life of the plums is so small, however, that it is most difficult to imagine that actual loss of

carbohydrate can be responsible for incidence of breakdown. The loss of acid on the other hand is very high and, as can be seen from Table X, is approximately 80 per cent. of the total for all Kelsey plums after eighty days in store. That exhaustion of the supply of acid coincides with the "death" of the apple [1] is a fact that has been repeatedly observed, although the actual part played by the acid in the metabolism of the apples has not been accounted for. In the case of the plums observed there is no doubt that "death" of the fruit coincided with lowering of the acid content to a very low and almost constant value.

Haynes (8) has shown that changes in acid content of apples can be expressed by a straight line if logarithms of acid concentrations be plotted against time in storage. She observed a deviation from the straight line curve with incidence of breakdown. In fig. 11 similar curves for logarithmic decline of acidity in the Gaviota and Kelsey plums are shown. The curves for the Gaviota plums are similar to those shown in fig. 7 and show two breaks: one after ten days in store, when rate of sugar consumption increased, and the second after forty-four days in store, when sugar consumption decreased and incidence of bladderiness in these plums was observed. Internal browning in the Kelsey plums was first observed on the fortieth day in Stages I and II, and on the sixtieth day in Stages IIA and III. No deviation from the straight line is observed at those times.

In all cases, however, incidence of breakdown was accompanied by a general disturbance and at times a reversal of the sugar equilibrium, suggesting a possible general disturbance of the nature of metabolism. In the Kelsey plums, Stages IIA and III, where incidence of internal browning was not so severe and not so rapid as in Stages I and II, this disturbance was not so great and proceeded at a much slower rate as can be seen by comparison of the rate of inversion of sucrose in Stages I and III.

The high rate of loss of acid observed in the Gaviota plums in the first ten days in store when there were no indications of internal breakdown, and the observation that there was no increase in rate of loss of acid with incidence of browning in the Kelsey plums, would seem to indicate that the actual rise in the rate of acid consumption (as noticed on the different occasions described above) was not a concomitant of internal breakdown, as stated by Haynes (8), but rather an overdraft on the stored acid due only to an insufficient supply of acid from oxidation of sugar necessary to keep up acid equilibrium. Premature breakdown, such as internal browning in the Kelsey plums, and bladderiness as observed in the Gaviota plums, would therefore seem to be due not to changes in the rate of respiration as measured by loss of sugar and acid, but to a probable disturbance in the

[1] Death is used in the sense of the end of the storage life of the fruit as evidenced by complete loss of flavour and onset of fungal attack in store or at room temperature.

actual nature of the physiological constitution of the fruit. Such a disturbance might possibly be caused by degradation of proteins (12), the accumulation of breakdown products possibly affecting the activity and rôle of enzymes. The changes in the sugar and acid equilibrium would

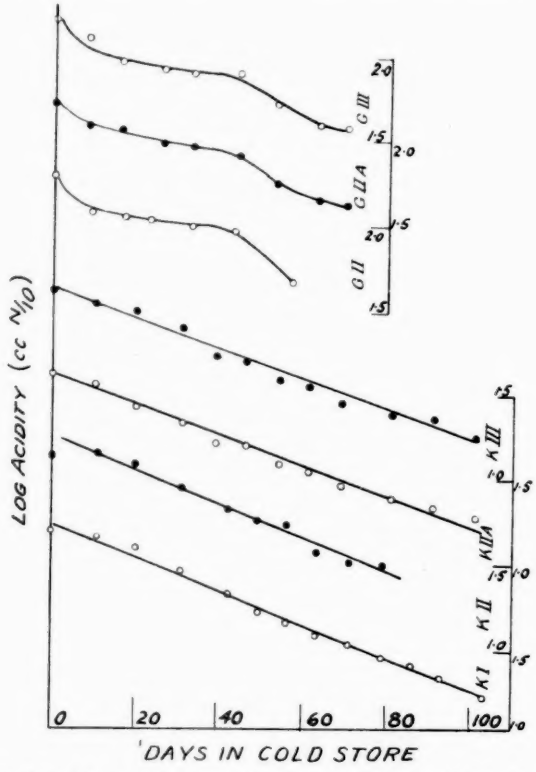

FIG. 11.—The logarithmic decline of acidity in the Kelsey and Gaviota plums with time in store.

then seem to be parallel results arising out of the cause of physiological breakdown. That internal browning has been observed in the Kelsey plums and not in the Gaviota might then be accounted for by differences in internal protoplasmic structure. This is substantiated perhaps by the actual differences in sugar and acid metabolism observed in these two varieties of plums. The cause of internal browning would then be inherent to the plum itself.

Premature breakdown, due to internal browning, and "death" of fruit should perhaps be differentiated. Such a differentiation would then account for the fact noted that exhaustion of acid generally coincided with the "death" of the fruit. In this connection storage results have indicated that complete loss of flavour and fungal attack in store took place when the acid content of Kelsey plums was reduced to a very low level. The storage life of the fruit would then appear to depend upon the rate of exhaustion of acid which is again regulated by sugar oxidation. The observation that rate of loss of acid in Kelsey plums, Stages IIA and III, which kept better than Stages I and II and showed a slower rate of acid loss, might then become significant. That rate of loss of sugar and acid in apples is controlled by the nitrogen content has been shown by Haynes and Archbold. Evidence is available from this investigation on plums, which seems to indicate that proportion of acid lost in store is dependent upon nitrogen content and is the same for all stages per unit of nitrogen for a similar period of time in store, but that the actual amount lost at any time is regulated by concentration of the acid. This can be seen from Table X. The constancy of the percentage of acid lost per unit of nitrogen in the different samples after a lapse of eighty days in store is definitely significant. Good keeping quality should therefore be correlated with low nitrogen and low acid content. This is actually the case with the Kelsey plums. From Table IX it can be seen that all plums that kept well had a low acid and low nitrogen content on picking. Such conditions are in their turn correlated with delay in time of gathering.

TABLE X.

AMOUNT OF ACID PER UNIT TOTAL NITROGEN LOST BY KELSEY PLUMS AFTER 80 DAYS IN STORE.

Sample.	Total Acid on picking. c.c. N/10.	Acid loss. c.c. N/10.	Acid loss as per cent. of total.
A. I	154·4	126	81·7
A. II	136·3	112·7	79·0
A. IIA	132·0	106·3	80·7
A. III	132·0	107·5	81·5
C. I	171·0	136·1	79·8
C. II	167·0	131·8	79·0
C. III	153·0	126·6	83·7
B. II	133·0	104·9	79·0
D. IIA	99·0	74·0	75·0

SUMMARY.

The effect of time of gathering on the changes in acid, H-ion concentration, and sugar content of the two varieties of plums (Gaviota and Kelsey) during subsequent storage at 34°–36° F. have been investigated. Four pickings of each variety of plum were made and approximately weekly analyses were carried out. In addition, analyses of Kelsey plums from three orchards were made on picking and after eighty days in store.

References are given for detailed descriptions of methods employed. A discussion of methods of expressing results is given and reasons are advanced for choosing unit Total Nitrogen as basis for the expression of the results of this investigation.

It was found that during the first ten days in store the sugar content of the Gaviota plums increased slightly. This was accompanied by a rapid loss of acid. During the next thirty-two days sugars were lost at a steadily increasing rate, while acid consumption declined markedly. The rate of inversion of sucrose was less than the rate of consumption of total sugar during that period. The reducing sugars which were lost consisted equally of fructose and glucose in the first picking, but the proportion of loss of fructose relative to glucose increased in the later pickings.

First appearance of bladderiness in all samples was noticed after about forty-four days in store. Simultaneously the rate of loss of sugar declined and the rate of acid consumption increased. A complete reversal of the sugar equilibrium was observed at that time in the last two pickings. The changes in the H-ion concentration were similar to those of total acid.

A marked difference was observed between the changes of the constituents of the first and second pickings and those of the third and fourth pickings of the Kelsey plums. In the first two pickings rate of loss of sugar was high during the first twenty days in store. It then declined and reached a minimum after about forty-two days. The rate of sugar consumption in the third and fourth pickings remained uniform throughout the observed storage life.

During the period of high sugar loss in the first and second pickings, acid was lost at a slow rate. With decrease in sugar consumption rate of acid loss increased and remained uniform throughout the remainder of the storage period. In the third and fourth pickings acid loss was uniform until about the sixtieth day in store. The rate of loss then decreased and remained steady.

Sucrose increased in the Kelsey plums of all pickings until about forty to fifty days in store. The great decrease in fructose compared to glucose during that period suggests that it was fructose that principally changed into sucrose.

After forty-two days in store plums of the first and second pickings showed onset of internal browning which increased rapidly. Browning in the third and fourth pickings was observed only after fifty-four days in store and it progressed very slowly.

Simultaneously with the onset of browning in the Kelsey plums a reversal of sugar equilibrium was noticed in all pickings. This reversal was rapid in the first two pickings but slow in the last two.

It was found that acid loss was high when sugar consumption was low and that rate of loss of acid did not increase with appearance of internal browning in the Kelsey plums. It is therefore suggested that increase in rate of loss of acid is not a concomitant of internal breakdown but rather an overdraft on stored acid due to insufficient supply of acid from oxidation of sugars necessary to maintain acid equilibrium. Premature breakdown would seem to be due to a disturbance of the nature of the physiological structure of the protoplasm, such as might be caused by protein breakdown.

It is indicated that the proportion of acid lost in store is dependent upon nitrogen content and is the same for all stages per unit of nitrogen for similar periods of time, but that actual amount of acid lost is regulated by acid concentration. Low nitrogen and low acid would therefore favour good keeping quality. This is correlated with delay in time of gathering of the Kelsey plums.

The author has pleasure in expressing his thanks to Professor Smeath-Thomas for providing the facilities of the Chemistry Department which made this work possible, and for the interest taken in this paper. He is indebted to Dr. W. E. Isaac for continued interest and advice and for his criticisms of the manuscript of this paper.

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University of Cape Town,
December 1934.

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THE ORGANIC MATTER CONTENT AND THE CARBON-NITROGEN RATIO OF SOUTH AFRICAN SOILS OF THE WINTER RAINFALL AREA.

By W. E. Isaac.

(Communicated by R. S. Adamson.)

(With one Text-figure.)

(Read March 26, 1935.)

Introduction.

The amount of organic matter contained in a soil is of importance to cultivators since this affects the physical character of the soil and also the amount of available nitrogen. The availability of soil nitrogen, however, is affected not only by the amount of organic matter but also by its carbon-nitrogen ratio. A knowledge of the range of carbon-nitrogen ratios obtaining within a climatic region may also serve as a guide to economical manuring of the land.

The winter rainfall area of South Africa which presents characteristic and circumscribed climatic and vegetational features offers an interesting field for investigations along these lines, more especially as most previous investigations have been carried out in cold temperate regions.

An extension of this investigation to the soils of the more arid regions has been undertaken, of which the results will be published subsequently.

A. The Organic Matter of the Soil.

(i) *Fractions of Soil Organic Matter.*—The organic matter of the soil consists of structural undecomposed plant and animal residues, of partly decomposed organic residues, and of structureless, slowly decomposing organic matter. Most of the undecomposed and partly decomposed structural organic matter is eliminated by careful sieving, and the greater part of the organic matter contained in a soil sample prepared for analysis consists of structureless,* slowly decomposing organic matter, although it is not possible to exclude altogether such structural organic matter as fine rootlets. Henceforth the organic matter of carefully sieved soil will be referred to as "soil organic matter." This soil organic matter in a

* The term is here used in an histological sense.

large number, if not in all, soils is of both ancient and of recent origin, but very predominantly of recent origin. The organic matter of ancient origin is derived from the parent rock, and its chief characteristic from the chemical point of view is its low C/N ratio. Miller's investigations would seem to show that in the case of secondary rocks comparatively little variation occurs in regard to the amount of nitrogen present, although in the case of carbon the limits are further apart (Miller, 1903). Accordingly Miller concludes that the organic matter of ancient origin must on the whole vary greatly in character. The percentage of the organic matter in the surface soil which is of ancient origin cannot be directly measured, but Russell estimates that at best, and assuming that no decomposition has taken place, it does not exceed 10 to 20 per cent. of the total organic matter of the surface soil (Russell, 1927). It will thus be clear that in most cases, for practical purposes, the organic matter of ancient origin is negligible.

(ii) *Estimation of Soil Organic Matter by Multiplying Carbon by the Factor*, 1·724.—The soil organic matter can be estimated in various ways, but up to the present the best values are obtained by multiplying the figure for organic carbon by the factor 1·724. This factor is based on the assumption—made by Van Bemmelen and Wollny, among others—that soil organic matter (or "humic substances" of the soil) contains 58 per cent. of carbon, and this view is founded on a considerable body of evidence. Other carbon factors have been suggested (*e.g.* Read and Ridgell, 1922: Robinson, McLean, and Williams, 1929) but—as Robinson *et alia* recognise—the matter needs further investigation before a change of factor is justifiable.*

(iii) *Soil Organic Matter and Humus.*—The question here arises as to the connection between the soil organic matter and humus. Waksman in his "Principles of Soil Microbiology" (second edition, 1931) applies the term "humus" to organic carbon content of soil $\times 1{\cdot}724$, and the synonymous use of these two terms is common. Waksman is, nevertheless, fully aware of the confusion which exists in regard to the content of the term "humus." In a letter to the writer he remarks: "The subject of humic acid has been so confused and so much misinterpreted that it has very little bearing upon our knowledge of the actual organic matter of the soil and the processes that lead to its formation in the soil." In recent literature on soil science there is a tendency to restrict the term "humus" to the fraction obtained by treating soil with dilute alkali and then reprecipitating with acid (*e.g.* Beckley, 1921; Page, 1922), and also to move away from the concept, which is not surprising considering the complexity and confusion of the subject. As Robinson, however, remarks in his book on

* A few soil investigators have estimated soil organic matter by multiplying nitrogen by a factor, usually 20. This will be dealt with later (p. 222).

"Soils" (Robinson, 1932), the fact that it is not possible with precision to extract and define a fraction of the organic matter of the soil represented by the term "humus" should not blind us to the value of such a term for theoretical purposes as applying to "the organic matter of the soil which has been decomposed and has lost its original structure," *i.e.* to the colloidal and relatively stable fraction of the organic matter of the soil.

(iv) *The Relatively Stable Character of Soil Organic Matter.*—In dealing with the organic matter of the soil we have referred to the structureless organic matter as *relatively* stable, since it undergoes constant although slow decay, yielding nitrates. This accounts for the fact that nitrates are still being leached out into the drainage water of a plot at Rothamsted which has been kept clear of vegetation, but exposed to rain and weather since 1870 (Russell, 1932). It also accounts in part for the fact that, other conditions being equal, the amount of "humus" in the soil decreases as we move from colder to warmer climates since the rate of decomposition will increase with an increase in temperature.

Some idea of the difference in the rate of decay of structural plant residues and the soil organic matter is obtained by comparing the carbon dioxide output from soil to which no organic material is added with that from the same soil under the same conditions of temperature and moisture to which structural organic matter is added. Thus the writer in a previous research found as an extreme instance a difference of 21 : 1 in the case of a *Terra Rosa* from the Gower Peninsula of South-west Glamorganshire, between a soil sample to which was added 1·5 per cent. of the oven dry weight of crushed linseed as compared to a sample kept under the same conditions of temperature and humidity but to which no organic matter was introduced (Isaac, 1933). We may add that the difference would probably have been somewhat greater if the soil samples had been passed through a 60- or a 90-mesh sieve instead of being passed through a sieve of 3 mm. mesh.

(v) *Soil Organic Matter as Affected by Climate, Texture of the Soil, and Topography.*—In addition to temperature the physical structure of the soil (Sievers and Holtz, 1926; Russel and McRuer, 1927), vegetation and particularly moisture have an influence on the soil organic matter content. An increase in humidity, other conditions being equal, results in an increase in the amount of soil organic matter. Precise investigations exist equating changes in the amount of soil organic matter with changes in temperature and precipitation. Sievers and Holtz have shown that for the soils of the Columbia Basin (State of Washington), east of the Cascade Mountains, the amount of organic matter in the soil increases with an increase in precipitation (Sievers and Holtz, 1923 and 1926). Russel and McRuer found that the nitrogen content of the virgin grassland

soils of Nebraska is considerably affected by rainfall, and curves are given, showing an increase in nitrogen content with an increase in rainfall. These workers regard texture, however, as the most important factor affecting the nitrogen content of the soil. Topography also has a modifying effect. Russel and McRuer point out that the conclusions for nitrogen apply also to the organic matter of the soil, ". . . for the two constituents bear a fairly constant ratio to each other both in extremes of rainfall and of texture" (Russel and McRuer, 1927). From his studies of the organic matter—climatic relationships of North American soils—Jenny (1930) comes to the general conclusion that for every "fall of 10° C. in annual temperature, the average total nitrogen and organic matter content of the soil increases two to three times, provided the precipitation-evaporation ratio is kept constant." This relationship holds for both prairie and forest vegetation. The organic matter—humidity relationship is not as clearly defined as the organic matter—temperature relationship, for the nitrogen and organic matter content of originally timbered soils, shows but little correlation with increasing humidity. In regard to grassland soils, however, "Within regions of *constant temperature*, the nitrogen and organic matter content . . . increases logarithmically with increasing *humidity factors*." In the northern and temperate region the rate of increase of organic matter with increasing humidity is greater than in the southern and subtropical region. (This is seen in a comparison of the soils of Canada and Texas.)

B. The Carbon-Nitrogen Ratio of Soil Organic Matter.

Previous investigations point to a more or less constant and characteristic ratio of carbon to nitrogen in soil organic matter. This ratio has usually been found to be of the order of 10–12 : 1. Most of these investigations, however, have been carried out in cool temperate regions, but C/N ratio figures are available also for warm temperate, subtropical, and tropical soils. Recent investigations indicate that the carbon-nitrogen ratio does not show clearly definable changes correlated with changes in temperature and humidity factors such as is shown in the case of the amount of soil organic matter. The outstanding principle of change in regard to carbon-nitrogen ratio is that it will tend to become narrower in moving from regions where conditions are less favourable to decay of organic matter to conditions where decay is more rapid, *i.e.* in moving from colder and more humid to warmer and drier climates. This follows as a deduction from what is known of the general character of decay in the soil—the carbon of added organic material being dissipated (as CO_2) much more quickly than the nitrogen. Still, it should be borne in mind that we are not here dealing essentially with a differential rate of decay so much as with the

differential loss of two elements from the soil, for while the greater part of the carbon is ultimately released as carbon dioxide a considerable proportion of the nitrogen is assimilated by soil micro-organisms and enters into the constitution of proteins which appear to be relatively resistant to decay. That we are dealing with a differential rate of dissipation of carbon and nitrogen is further indicated by the fact that the nitrogen of the soil organic matter (or "humus") seems more available to micro-organisms than the residual carbon. If Waksman's theory of the microbial origin of the nitrogen fraction of the soil organic matter is correct, then the density and character of the soil micropopulation might have an effect not only on the rate of decay but also on the character of the more or less stable soil organic matter. Further, the intensity of microbial activities depends not only on total numbers, but also on the environmental conditions as affecting physiological efficiency (*e.g.* Fred and Hart, 1915; Chudiakow, 1926). Thus a decrease in numbers of soil micro-organisms might have a greater effect on the C/N ratio than on the rate of decay.

(i) *Variation of C/N Ratio of Soil Organic Matter in Relation to Climatic Conditions.*—At present there is not a great deal of evidence available for testing out these theoretical possibilities, and we have already drawn attention to the most outstanding result of recent investigations, viz.: that the C/N ratio of soils does not show obvious changes correlating with changes in temperature and humidity factors. Sievers and Holtz showed that the organic matter content of the Columbia basin soils increases with increased precipitation, but that the C/N ratio remains nearly constant (Sievers and Holtz, 1923). "By comparing the averages of all nitrogen-carbon ratios for soils receiving ten inches or less of precipitation with those receiving fifteen inches or more . . ., we find a slightly narrower ratio for the more arid soils." The average C/N ratio for seven soils from a region of ten inches or less (7·5–10 inches) rainfall per annum was found to be 11·1 : 1, or, omitting one soil—deviating from the others to a marked extent (8·1 : 1)—the C/N ratio becomes 11·6 : 1. In the case of six soils from regions receiving 15–21·5 inches per annum (average = 16·9 inches), the average C/N ratio was found to be 13·1 : 1, or, eliminating one soil of greater deviation than the others, the ratio is 12·7 : 1. In a later publication (Sievers and Holtz, 1926) these authors present evidence to show that there is a tendency for the C/N ratio to become wider with higher nitrogen content, and since, as we have already seen (Jenny, 1930; Russel and McRuer, 1927), higher nitrogen has been correlated with decreasing temperature and increasing humidity, this conclusion agrees essentially with those previously put forward by the two authors. In regard to temperature, Jenny points out that the C/N ratio seems to become wider with decreasing temperature, but shows less variation in relation to variations in humidity

factors, since it remains approximately constant at 11·3 : 1 along the isotherm of 11° C., and is nearly the same in both timber (10·9) and grassland (11·6) soils (Jenny, 1930).

In this connection it will be interesting to consider the results obtained by McLean (1930) in an investigation of the C/N ratios of fifty British soils and sixteen foreign soils. The average C/N ratio of the British soils is 10·2±0·3 : 1. McLean points out that " . . . the results form a normal frequency curve with a well-defined maximum at 9·5–10·4 : 1, although the range is fairly considerable, viz., 6·5–13·5 : 1." Within limited areas, however, an approximately constant ratio was obtained whether the soil was of low or of high organic matter content. In regard to the sixteen foreign soils examined, a very wide range of carbon-nitrogen ratios was obtained, varying from 2·0–23·0 : 1. Here again, within limited areas, the C/N ratio was found to remain approximately constant. McLean comments: "Without further study, however, it is impossible to estimate the significance of this result."

(ii) *Variations of Carbon-Nitrogen Ratio in Relation to Depth.*—Up to the present we have considered the C/N ratio of the soil without reference to depth. It is well established that the organic matter content of the soil decreases with depth, but it is perhaps not so clear that the C/N ratio should vary with depth. The somewhat meagre investigation of this matter indicates, however, that the C/N ratio of soil organic matter becomes narrower with increasing depth. The investigations of Sievers and Holtz present fairly ample evidence in favour of this view (Sievers and Holtz, 1923 and 1926). The data presented by these workers also indicate that whereas the C/N ratio of the soil organic matter (0–6 inches) is affected by precipitation, that of the subsoil (12–48 inches, at intervals of 12 inches) remains surprisingly uniform irrespective of the variations in precipitation within the area of investigation. Variations in precipitation have also but little influence on the organic matter content of the subsoil, and thus differences in composition between surface and subsoil become more pronounced in regions of heavier precipitation. Leighty and Shorey studied the variations of C/N ratio in fifty-five soil profiles from twelve of the United States of America, and in forty-five cases there was a decided and unbroken narrowing of the C/N ratio with increasing depth. In one case only was there a decided increase of C/N ratio with depth; in two cases there was a rise in the C/N ratio and then a fall; and in seven cases (two of doubtful significance) there was at first a narrowing followed by a widening of the C/N ratio at a greater depth * (Leighty and Shorey, 1930). Lastly, McLean presents data for two soil profiles at Aber, North Wales (McLean, 1930). The vegetative cover in one case was bracken (*Pteris aquilina*), and in the other

* These data obtained from Table I (pp. 259–263).

Vaccinium. Under bracken the C/N ratio for the first two inches of soil was found to be 13·9 : 1. For the depth level, 2 to 6 inches, the C/N ratio was found to be 11·5 : 1. Thereafter the C/N ratio was found to remain more or less constant to a depth of 30 inches—samples being taken at six-inch intervals. Under *Vaccinium*, however, there was a constant decrease of C/N ratio with increasing depth, ranging from 16·5 : 1 at a depth of 2 to 4 inches to 11·6 : 1 at a depth of 24 to 30 inches. The top two inches of this second profile was not examined as: "It consisted of a peaty matted layer which presented great difficulties in sampling." McLean also adds: "The high figure for the C/N ratio in the top layer of the profiles may be attributed to the presence of unhumified organic matter" (McLean, 1930).*

C. Previous Investigation of the Organic Matter Content and C/N Ratio of South African Soils.

There has previously been no critical investigation of the organic matter content of South African soils. Juritz, in his book "A Study of the Agricultural Soils of Cape Colony" (Juritz, 1909), gives organic matter values as determined by loss of weight on ignition for 745 soils, but in the case of some of these the ignition loss figure is not corrected for loss of carbon dioxide by the decomposition of carbonates. Figures for organic matter determined in the same way are given also in other publications by Juritz. Organic matter values obtained by ignition loss, however, are not reliable, and this method is now widely recognised to be unsatisfactory since the figure obtained will incorporate the bound or colloidal water of the soil, which in the case of clays may account for 50 to 70 per cent. of the total loss in weight on ignition after correcting for loss in weight due to decomposition of carbonates. The unsatisfactory character of the method was recognised by Juritz, who points out (pp. 7–8) that the ignition loss value of oven-dried soil includes "organic matter, water of combination, ammonium salts, etc."

There has been no previous investigation of the C/N ratios of South African soils, but attention may be called to five C/N ratio values determined during the course of other investigations. In a recent Science Bulletin issued by the South African Department of Agriculture, C/N values are given of two red loam soils of the Northern Transvaal (Kamerman and Klintworth, 1934). The values are of the 10 : 1 order (averages of 9·9 : 1

* We may also call attention to references made by Vageler to variation of C/N ratio with depth in the case of tropical soils. "The ratio of carbon to nitrogen (C/N ratio) in humus varies in the humid tropics from about 8 to 12 at the surface, sinking sometimes to 4 in the subsoil of very acid soils, but reaching 15 to 16 at their surface" (Vageler, 1930, translated by Greene, 1933). There are, however, no citations of literature.

and 9·2 : 1). McLean (1930) records the following C/N ratios of three South African soils: Transvaal, 14·2 and 14·4; Natal, 14·7.

Methods.

Collection and Preparation of Soil Samples.

In most cases soil samples were obtained by digging a number of small trenches large enough to allow a man to work inside and with a clean spade to cut off from the sides a number of thin soil slices to the required depth. Where the soil was shallow, or where there were no facilities for digging, a borer was used.

Samples were taken to a maximum depth of 3 feet. When it was possible to go to this depth, it was sufficiently deep in most cases to include the whole of the soil layer proper (or A-horizon) as well as a good deal or the whole of the subsoil (or B-horizon). Where soil and subsoil were differentiated within the three-foot limit, separate samples of each were generally taken. In the case of soils extending to the three-foot limit or beyond, either a sample was made for the whole of the 3 feet ("Bizweni" No. 1 and No. 2) or else two samples were made, one at a higher and a second at a lower level (Kirstenbosch No. 3), in the latter case the upper and lower limits of the two samples coinciding with the surface of the soil and the 3-foot level respectively. The series of soils studied includes two very shallow soils (Kirstenbosch No. 1, and Bredasdorp No. 1). The localities from which soils were collected are shown in fig. 1.

After the soil had been collected it was thoroughly mixed and then quartered until a sample of about 15 lb. was obtained. From this a sample was withdrawn and put into a clean and stoppered container and set aside for p_{H} determinations.

The remaining bulk of soil was spread out in the laboratory to dry, and when air-dry any lumps of soil contained in the sample were pounded with a pestle, care being taken not to crush any stones. The soil was then passed through a 2-mm. sieve and freed as much as possible of fine rootlets, parts of small insects, and any other structural organic matter; and after quartering, the sieved soil was stored in well-stoppered bottles until analysed. Before analysis a portion of soil was further pounded to pass a 90-mesh sieve, since Robinson and his co-workers found it necessary to grind the soil to a very fine powder in order to ensure satisfactory results in estimating soil organic carbon (Robinson, McLean, and Williams, 1929). The soil material remaining on the 90-mesh after sieving was, after further pounding, added to that which had passed through the sieve.

A portion of finely powdered soil was dried to constant weight in an electric oven at 105° C., and all calculations were made on an oven dry-weight basis.

Nitrogen Estimation.

Total nitrogen was determined on 10 gm. soil samples by the Kjeldahl method, the ammonia being distilled into N/10 hydrochloric acid and methyl red used as indicator, or in the case of the nitrogen determinations carried out by Mr. B. Gershill the ammonia was distilled into boric acid solution, and bromo-phenol blue used as indicator (Scales and Harrison, 1920).

Carbon Determination.

This is best estimated by the dry combustion method, correction being made for the carbon dioxide derived by the decomposition of carbonates. In practice, however, this method is inconvenient as each determination is apt to take a long time and facilities are frequently lacking for conducting more than one or two determinations at a time. Thus a number of more rapid wet combustion methods have been developed which result in the oxidation of about 80 to 90 per cent. of the soil organic matter. Most of these methods depend upon an estimation of the amount of chromic acid decomposed during the oxidation of soil organic carbon by a sulphuric-chromic acid mixture.

In the present investigation the sulphur dioxide reduction method of Robinson and his co-workers was used (Robinson, McLean, and Williams, 1929). This method depends upon the reduction of iodine by sulphur dioxide evolved by the action of concentrated sulphuric acid upon soil organic carbon. The excess iodine is titrated against sodium thiosulphate of known strength. Since *ex hypothesi* $C = 2SO_2 = 4I$, 1 c.c. of a normal iodine solution is equivalent to 0·003 gm. carbon. This method (which is essentially a Kjeldahl digestion) does not entail a correction for carbonates, and the results obtained by Robinson *et alia* by its use averaged 89·6±1·03 per cent. of the dry combustion figures. Thus the values obtained by this method should be corrected by the factor 1·116 to give a measure of the organic carbon content of the soil. The values obtained with the sulphur dioxide reduction method compare very favourably with those obtained with other wet combustion methods. Certainly the method was found to give very satisfactory agreement between duplicates at the Capetown University laboratories. Results not agreeing within 5 per cent. were rejected in the present investigation, but generally the results were well within 3 per cent. and not infrequently the results agreed almost exactly. The greater deviations, up to 5 per cent., were sometimes experienced in dealing with subsoils of very low organic matter content. Most of the soils dealt with had a much lower carbon content than the soils with which Robinson and his colleagues worked. For this reason it was considered advisable to carry out the nitrogen determinations on separate

and larger soil samples, since low carbon implies also low nitrogen. Details of the method will be found in Robinson's paper.

In most cases 5 gm. samples of air-dry soil were used for the carbon determinations.

N/2 solutions of both iodine and sodium thiosulphate were used, the sodium thiosulphate solution being standardised against dessicated G.R. potassium iodate (Kolthoff and Furman, 1929).

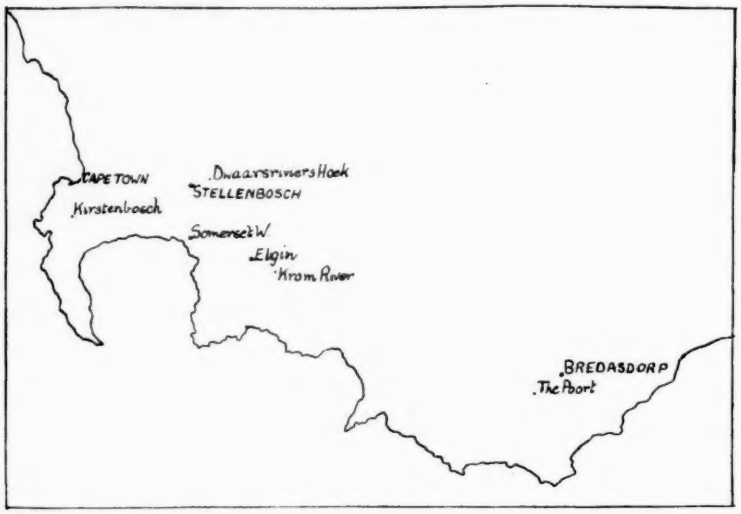

FIG. 1.—Diagram of the South-western corner of the Cape Province. The localities from which soil samples were collected are indicated in italics.

The carbon and nitrogen determinations marked by an asterisk in the tables that follow were carried out by Mr. B. Gershill of the Chemistry Department.

Organic Matter Values.

Organic matter was estimated by multiplying the organic carbon by the factor 1·724. The validity of this method has already been dealt with in the introductory section (p. 206).

Hydrogen-ion Concentration.

This was determined colorimetrically on fresh soil samples.

Experimental.

As will be seen from fig. 1, the soils studied were collected over a fairly wide area. Taken as a whole these soils are of the Brown Earth type which is the more characteristic type of the South-western Cape region (Shantz and Marbut, 1923). The soils studied are relatively shallow, and with the exception of Bredasdorp No. 1 they are acid in reaction. In this respect also they are typical of the South-western Cape soils.

The prevailing climatic conditions are those typical of Winter Rainfall regions. The total annual precipitation shows considerable variation from 20·22 inches for Bredasdorp to 57·38 inches for Kirstenbosch (Lewis, 1927); but in all cases the greater part of the rainfall (60 to 70 per cent.) is in winter.

The soils studied can be grouped as follows:

(A) Somerset West. "Bizweni" Farm. Low lying orchards. Two soils.
(B) Dwaarsriviers Hoek. Highland orchards. Three soils.
(C) Elgin District. Highland orchards.
  (i) "Glen Elgin." One soil.
  (ii) Krom River Farm. One soil.
(D) Kirstenbosch.
  (i) Cultivated soils. Three soils.
  (ii) Pinewood soil. (Virgin).
(E) Bredasdorp District. (The Poort).
  Virgin soil over "recent limestone" and under sclerophyllous vegetation.

(A) Somerset West. Altitude, 119 feet.
Rainfall, 25·76 inches per annum (Lewis, 1927).
Underlying rock, Malmesbury.

"*Bizweni*" *No.* 1.—Plum orchard (Gaviota).

Profile: The depth of the soil varies a good deal due to the undulating character of the subsoil. The soil, however, is rarely less than 3 feet deep. Soil samples taken from a depth of 0–3 feet. The soil is of a greyish-brown colour.

p_H, 6·2.

"*Bizweni*" *No.* 2.—Plum orchard (Kelsey).

Profile, Colour } As under "Bizweni" No. 1.

p_H, 6·1.

The carbon, nitrogen, C/N ratio, and organic matter content of these two soils are given in Table I. below.

TABLE I.

Soil.	Organic carbon, per cent.	Nitrogen, per cent.	C/N ratio.	Organic matter, C × 1·724.
"Bizweni" No. 1 .	1·33	0·085	15·6 : 1	2·29
"Bizweni" No. 2 .	0·94*	0·084	11·2 : 1	1·62

In this series it will be noticed that the soil with the higher organic matter content has the wider C/N ratio, and that the nitrogen content of the two soils is of the same order, the difference in C/N ratio being due to a higher organic carbon content in "Bizweni" No. 1.

(B) Dwaarsriviers Hoek. Altitude, approx. 1100 feet.
Rainfall, 48·06 inches per annum (1911–1934).*

Dwaarsriviers Hoek No. 1.—Plum orchard (Kelsey).

Soil, a riverine deposit.

Profile: Soil, 0–2 feet. Greyish-black colour.

p_H, 6·4.

Subsoil, 2 feet—diggings to 3 feet.
Well differentiated from soil. Of a medium brown colour.

p_H, 5·7.

Dwaarsriviers Hoek No. 2.—Plum orchard (Kelsey).

Soil derived from granite.

Profile: Soil, 0–1 foot. Medium brown colour.

p_H, 6·9.

Subsoil, 1 foot–2½ feet. Yellowish-brown colour and fairly well differentiated from soil.

p_H, 5·8.

Dwaarsriviers Hoek No. 3.—Plum orchard (Gaviota).

Soil derived from granite.

Profile: Soil, 0–18 inches. Medium brown colour.

p_H, 6·4.

* I wish to thank Mr. A. C. Buller for supplying the rainfall data for Dwaarsriviers Hoek.

Subsoil, 18 inches—diggings to 3 feet.
Yellowish-brown in colour.

p_H, 5·6.

The carbon, nitrogen, C/N ratio, and organic matter content of these three soils and subsoils are given in Table II.

TABLE II.

	Dwaarsriviers Hoek No. 1.		Dwaarsriviers Hoek No. 2.		Dwaarsriviers Hoek No. 3.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Organic carbon, per cent.	1·26	0·54	1·19	0·45	0·84	0·42*
Nitrogen, per cent.	0·078	0·044	0·078	0·035	0·058*	0·039*
C/N ratio .	16·1 : 1	12·3 : 1	15·2 : 1	12·8 : 1	14·5 : 1	10·7 : 1
Organic Matter (C × 1·724).	2·17	0·93	2·05	0·78	1·45	0·72

Table II shows the following interesting features:—

(1) The C/N ratio narrows with decreasing organic matter content of soil.

(2) In each of the three cases, the organic carbon and the organic nitrogen and therefore the organic matter, decreases in amount in passing from the soil to the subsoil.

(3) Since the carbon shows a relatively bigger decrease in passing from soil to subsoil, the C/N ratio of the subsoil is narrower than that of the soil.

(C) Elgin District.—Altitude, about 900 feet.
Rainfall (Elgin Plantation): 41·89 inches per annum (Lewis, 1927).
This rainfall figure is the only one available for both "Glen Elgin" estate and Krom River Farm.

"*Glen Elgin*."—Plum orchard (Kelsey and Gaviota).
Soil derived from Bokkeveld shales.
Profile: Soil, 0–1 foot. Rich brown colour and stony.
After passing through a 2-mm. sieve, the sample is still stony. (Very small stones.)

p_H, 6·6.

Subsoil, 1 foot–18 inches. Reddish-brown colour and very stony—more so than the soil.

As in the case of the soil, after passing through a 2-mm. sieve, subsoil still stony.

p_H, 6·1.

*Krom River Farm.**—(Peach orchard). Situated on a hillside.

Soil derived from Bokkeveld shales.

Profile: Soil, 0–10 inches to 1 foot, and of a fairly dark brown colour.

p_H, 6·4.

Subsoil: (i) 4 to 6 inches in depth. More gravelly and stony than the soil and of a lighter brown colour.

p_H, 6·0.

(ii) "Pot" clay. Brown and stiff with many large stones.

This clay is derived by weathering from the underlying rock.

In Table III below will be found the figures for the organic carbon, nitrogen, C/N ratio, and organic matter for the two soils and subsoils of the Elgin district.

TABLE III.

	"Glen Elgin."		Krom River Farm.	
	Soil.	Subsoil.	Soil.	Subsoil.
Organic carbon, per cent.	2·83	1·53	1·95	1·84
Nitrogen, per cent. . .	0·166	0·107	0·127	0·117
C/N ratio . . .	17·1 : 1	14·3 : 1	15·3 : 1	15·7 : 1
Organic matter (C × 1·724)	4·88	2·63	3·35	3·17

As in the case of the "Bizweni" soils and the soils collected at Dwaarsriviers Hoek, the two Elgin soils show a narrowing C/N ratio with a decrease in total organic matter in the soil. The same phenomenon is also seen in the case of the two Elgin subsoils.

In the case of "Glen Elgin" soil, there is a decided narrowing of the C/N ratio in the subsoil as compared with the soil. In the case of Krom River Farm, however, the C/N ratio of the soil is a little lower than that

* This soil profile has been described by the writer in a previous paper (Isaac, 1934), and it is noted here for the sake of completeness. In that paper the underlying rock is referred to by mistake as Malmesbury slate.

of the subsoil, but it should be borne in mind that the total organic matter shows but little decrease in the subsoil as compared with the soil.

(D) Kirstenbosch. Altitude, 300–350 feet.
(Altitude range for soils collected).
Rainfall, 57·38 inches per annum (Lewis, 1927).

Kirstenbosch No. 1.

Soil derived from Table Mountain Sandstone and under a tree cover, the dominant tree being *Pinus pinaster.**

Profile: Soil, 4 to 6 inches deep and only in relatively few places reaching a depth of 6 inches. Black in colour and clearly marked off from the subsoil, which seems to be mostly barren sand. The whole profile, particularly below the "soil" level, is very stony. It may be remarked that many of the trees show very shallow rooting systems.

p_H, 4·7.

Kirstenbosch No. 2.

Field under cultivation for oats.

The soil lies over rubble brought down the mountain side, chiefly Table Mountain Sandstone. Soil of a greyish-brown colour.

The soil is variable in depth but generally extending to a depth of about 9–10 inches, but in some places only 6 inches while in others it may extend to a depth of 11 inches. At the margin of the field the soil in places goes to a depth of only 4 inches.

Soil samples for analysis taken to a depth of 9 *inches.*

p_H, 5·6.

Kirstenbosch No. 3.

An old vlei soil of black colour cultivated at intervals over many years.

Profile: Diggings were made about the middle of August to a depth of over 4 feet, but no differentiation into horizons was evident. Before a depth of 4 feet was attained, the water table had been reached.

* *Pinus pinaster* is a native of the Mediterranean and is the most widely planted conifer in South Africa. The exact date of introduction is not known, but it had certainly been brought to the Cape by 1800 and probably by the Huguenots. It has found South African conditions, especially those of the Winter Rainfall region, very favourable, and has shown considerable natural regeneration, although the extent of land colonised in this way is not known. The area of Kirstenbosch under consideration is not a plantation and has never been one, but it has been colonised by *P. pinaster*, which exists along with other introduced (*e.g.* oak) and native (*e.g. Podalyria calyptrata*) trees.

Two samples were made:
(*a*) High level, 0–9 inches.
(*b*) Low level, 27–36 inches.
p_H determinations: 0–16 inches, 5·8.
27–36 inches, 6·0.

***Kirstenbosch No.* 4.**

Soil derived from granite and occurring on a North-facing slope. Soil cultivated largely for the growing of Buchu (*Barosma*).

Profile: Soil, 0 to 28 inches. In places extending to a depth of 32 inches. Rich brown colour.

p_H, 5·6.

Subsoil: this extends to a depth below 3 feet.
The subsoil is of a lighter brown colour than the soil.
Both soil and subsoil are very fine, and after air-drying nearly the whole of the sample passed through a 2-mm. sieve.
Analysis given of soil only, for a depth of 0–9 inches.

The carbon, nitrogen, C/N ratio, and organic matter content of these four soils are given below in Table IV.

TABLE IV.

Soil number.	Organic carbon, per cent.	Nitrogen, per cent.	C N ratio.	Organic matter, C × 1·724.
Kirstenbosch No. 1 :				
Soil	3·96*	0·147*	26·9 : 1	6·82
Subsoil . . .	0·84*	0·037*	22·6 : 1	1·44
Kirstenbosch No. 2 . .	1·55*	0·123*	12·6 : 1	2·67
Kirstenbosch No. 3 :				
High level . . .	1·85	0·081*	22·9 : 1	3·19
Low level	1·83	0·071*	25·7 : 1	3·15
Kirstenbosch No. 4 .	1·36*	0·090*	15·1 : 1	2·34

If we arrange the soils only in order of increasing organic matter content and arrange the corresponding C/N ratios in a series we do not find here the unbroken parallelism shown by the other series. Kirstenbosch No. 4 falls out of series. Still, on the whole an essential parallelism is seen between total organic matter content and C/N ratio, increasing soil organic matter being accompanied by a widening C/N ratio.

Kirstenbosch No. 1 shows a marked narrowing of C/N ratio in passing from soil to subsoil. There is also, however, a very marked decrease in

soil organic matter. In the case of Kirstenbosch No. 3 there is no morphological differentiation into soil and subsoil, and it may be said that there is no significant decrease in soil organic matter within a depth of 3 feet. The C/N ratio remains of the same order throughout, but widens somewhat with increasing depth. The C/N ratios recorded fall into two distinct sets. One set of the order of $25 \pm 2 : 1$, and the other set of the order of $14 \pm 1 : 1$. The first set includes a virgin soil (Kirstenbosch No. 1), the second set comprises only soils that have been cultivated for many years.

(E) Bredasdorp District. Altitude, 220 feet.
Rainfall, 20·22 inches per annum (Lewis, 1927).

Bredasdorp No. 1 (The Poort).

Hillside and summit soil over "recent limestone" and under South-western Cape vegetation. There is no continuous layer of soil, but soil accumulates in the clefts and holes of a rock pavement. Depth variable, but mostly very shallow, a depth of 3 inches being exceptional. In a very few places, however, the soil may extend to decidely greater depths, $7\frac{1}{4}$ inches being recorded as the maximum. The soil is sandy and black in colour and, of course, showing no suggestion of a differentiation into soil and subsoil.

p_{H}, 7·8.

It is here necessary to append a few remarks on the sieving of this soil for carbon and nitrogen determinations, since this presented a certain amount of difficulty, as the soil consists essentially of fine sand with an admixture of very fine, black, powdery "humus," together with a high percentage of root fibres. The appearance of the soil suggests the presence of a relatively high percentage of "humus charcoal," and the seasonal distribution of the rainfall and the shallow character of the soil could certainly be regarded as contributory conditions to the production of such a soil (Vageler, 1933; pp. 104–105, p. 177).

The presence of a considerable quantity of fine root material made it impossible to pulverise the soil so as to pass through a 90-mesh without including a considerable proportion of structural organic matter in the sample for analysis. Thus it was decided to let as much soil as possible pass through the 90-mesh with gentle grinding and rejecting all the material that did not pass through. In this way a sample practically free from structural organic matter was obtained, although the percentage of sand present was probably too low.

The organic carbon, nitrogen, C/N ratio, and organic matter content of this soil are given below.

Organic Carbon : 12·33 per cent.
Nitrogen : 0·716 per cent.
C/N ratio : 17·2 : 1.
Organic Matter : 21·25 per cent.
(C × 1·724).

A Comparison of the Organic Matter of the Soils Studied, Estimated on a Basis of Carbon and of Nitrogen.

Some investigators have preferred to estimate soil organic matter by multiplying the soil nitrogen by a factor, usually a factor 20. This method has given satisfactory results in certain cases (*e.g.* Russel and McRuer, 1927). The data obtained by Read and Ridgell indicate that the use of a conventional nitrogen factor would give a more reliable indication of the organic matter content of the soil than carbon × 1·724 (Read and Ridgell,

Table V.

Soils.	C × 1·724 per cent.	N × 20 per cent.
Dwaarsriviers Hoek No. 3	1·45	1·16
"Bizweni" No. 2	1·62	1·68
Dwaarsriviers Hoek No. 2	2·05	1·56
Dwaarsriviers Hoek No. 1	2·17	1·56
"Bizweni" No. 1	2·29	1·70
Kirstenbosch No. 4	2·34	1·80
Kirstenbosch No. 2	2·67	2·46
Kirstenbosch No. 3	3·19	1·62
Krom River Farm	3·35	2·54
"Glen Elgin"	4·88	3·32
Kirstenbosch No. 1	6·82	2·94
Bredasdorp No. 1	21·25	14·32
Subsoils.		
Dwaarsriviers Hoek No. 3	0·72	0·78
Dwaarsriviers Hoek No. 2	0·78	0·70
Dwaarsriviers Hoek No. 1	0·93	0·88
Kirstenbosch No. 1	1·44	0·74
"Glen Elgin"	2·63	2·14
Krom River Farm	3·17	2·34
Soil (lower level).		
Kirstenbosch No. 3	3·15	1·42

1922). In general, however, the use of nitrogen values as a basis for estimating the soil organic matter has not been favoured, since the evidence for this procedure is somewhat slender and uncertain, and its use is based on the assumption of a more or less constant C/N ratio of 10–12 : 1. On the other hand, the use of the factor 1·724 for converting soil organic carbon to terms of soil organic matter is based on a considerable mass of investigation.

In view of the divergent opinions, Table V (p. 222) gives the organic matter contents of the soils and subsoils studied, calculated on the basis of carbon (C × 1·724) and of nitrogen (N × 20).

The organic matter calculated on a basis of nitrogen differs considerably from the values obtained on a basis of carbon, and in all but two cases the values are lower than those obtained with the carbon factor. When the value obtained on a basis of nitrogen is higher than the value obtained on a basis of carbon, the difference between the two values is not

TABLE VI.

Soils.	Per cent. carbon in N × 20.
"Bizweni" No. 1	78·25
"Bizweni" No. 2	55·95
Dwaarsriviers Hoek No. 1	80·78
Dwaarsriviers Hoek No. 2	76·28
Dwaarsriviers Hoek No. 3	72·41
"Glen Elgin"	85·25
Krom River Farm	76·78
Kirstenbosch No. 1	134·7
Kirstenbosch No. 2	63·01
Kirstenbosch No. 3 :	
(*a*) High level	114·2
(*b*) Low level	128·9
Kirstenbosch No. 4	75·54
Bredasdorp No. 1	86·10
Subsoils.	
Dwaarsriviers Hoek No. 1	61·37
Dwaarsriviers Hoek No. 2	64·28
Dwaarsriviers Hoek No. 3	53·84
"Glen Elgin"	71·50
Krom River Farm	78·63
Kirstenbosch No. 1	113·5

great (3·7 per cent. and 8·3 per cent.; C × 1·724 being taken as 100). Also in these two cases the C/N ratio is narrow—11·2 : 1 and 10·7 : 1, these being the narrowest C/N ratios recorded.

In general terms such a result was to be expected, since it is necessary to work out the nitrogen factor for each series of soils, and before this can be done the C/N ratios must be ascertained and then this factor can only be used for relatively homogeneous soil series.

The unsuitability of the nitrogen factor is still more clearly seen if we calculate the percentage carbon (obtained by direct estimation) in N × 20. See Table VI (p. 223).

The only values within a deviation of 5 either way of 58 per cent. (the basis of the factor, 1·724) are:

Soils: "Bizweni" No. 2 (−2); Kirstenbosch No. 2 (+5).
Subsoils: Dwaarsriviers Hoek No. 1 (+3·4); Dwaarsriviers Hoek No. 3 (−4).

We may also note Dwaarsriviers Hoek No. 2 (+6·3). All these soils and subsoils have relatively narrow C/N ratios. In order—11·2, 12·6, 12·3, 10·7 and 12·8. These are all the narrowest C/N ratios.

The values obtained for Kirstenbosch No. 1 soil and subsoil and Kirstenbosch No. 3 high and low level are particularly instructive.

Similar results were obtained by Leighty and Shorey, who only occasionally found an agreement in organic matter content calculated on a basis of N × 20 as compared with C × 1·724 (Leighty and Shorey, 1930). In the present investigation the maximum differences were found to be 54·9 and 56·9 per cent. (C × 1·724 being taken as 100).

Organic Matter Content and C/N Ratio in Relation to Rainfall.

In the introductory section of this paper we have dealt with some previous investigations relating to the effect of variations in precipitation on the organic matter content of the soil and on the C/N ratio of the soil organic matter (p. 209). In general, these investigations indicate that the amount of precipitation has a marked effect on the organic matter content, but a much smaller effect on the C/N ratio. It should be noted, however, that within a region of more or less uniform temperature the moisture–organic matter relationship is modified by the texture of the soil.

Below will be found summarised the organic matter content and the C/N ratio data obtained during the present investigation considered in relation to the rainfall of the localities from which the soils were collected.

The data presented are very few to serve as a basis for correlation between rainfall on the one hand and organic matter content and

A. Soils.

Rainfall and locality.	Organic matter, per cent.			C/N ratio. (N = 1)		
Kirstenbosch, 57·38 inches per annum.	6·82 (virgin)			26·9		
	3·19			22·9		
	2·67	**2·73**	**3·76**	12·6	**16·9**	**19·4**
	2·34			15·1		
Dwaarsriviers Hoek, 48·06 inches per annum.	2·17			14·5		
	2·05	**1·89**		15·2	**15·3**	
	1·45			16·1		
Elgin District, 41·89 inches per annum.	3·35	**4·12**		15·3	**16·2**	
	4·88			17·1		
Somerset West, 25·76 inches per annum.	1·68	**1·98**		11·6	**13·6**	
	2·29			15·6		

Bredasdorp No. 1 is not included, as it is an exceptional and peculiar soil.

B. Subsoils.

Rainfall and locality.	Organic matter, per cent.		C/N ratio. (N = 1)	
Kirstenbosch, 57·38 inches per annum.	3·15 (lower soil level)	**2·294**	25·7	**24·2**
	1·44 (virgin)		22·6	
Dwaarsriviers Hoek, 48·06 inches per annum.	0·93		12·3	
	0·78	**0·81**	12·8	**11·9**
	0·72		10·7	
Elgin District, 41·89 inches per annum.	3·17	**2·90**	15·7	**15·0**
	2·63		14·3	

carbon/nitrogen ratios on the other. This is particularly the case when the following considerations are borne in mind:—

(*a*) The localities from which the soils have been collected do not, taken together, represent an uniform, temperature region (*cf.* Somerset West and Kirstenbosch).*

(*b*) The soils present an heterogeneous assemblage in respect of topographical situation, texture, virgin or cultivated, and in the latter case the period of cultivation. All of these factors affect the organic matter content.

* Temperature data for the Union of South Africa are very difficult to obtain.

The data tabulated above show no correlation between the average organic matter content of the soil groups and the average annual precipitation. Temperature factors are neglected due to the lack of precise data. The same lack of correlation is seen between the C/N ratios and the rainfall data, although in this respect the C/N ratios of the soils show a closer parallelism with rainfall as compared with total organic matter content.

Conclusions and Discussion.

An examination of the C × 1·724 values contained in this paper indicates the relatively low organic matter content of the soils of the South-West Cape, a fact well known to the progressive farmer. Low organic matter content is regarded as being correlated with a narrow C/N ratio, and this certainly seems to be the case within a climatic region. The level of C/N ratios for the soils investigated, however, is very decidedly above the 10–12 : 1 ratio. The values obtained range from 11·2 : 1 to 22·9 : 1, and only two of the twelve soils have C/N ratios of the order of 10–12 : 1; these have the values 11·2 : 1 and 12·6 : 1. As would be expected, the subsoils have lower C/N ratios, but here also only three out of six—or including a low level soil sample, three out of seven—showed a C/N ratio of the 10–12 : 1 order. The subsoil C/N ratios of this order were 10·7 : 1, 12·3 : 1, and 12·8 : 1. The average C/N ratio of the twelve soils studied is 16·6 : 1, and the average C/N ratio of the cultivated soils is 15·6 : 1. If we exclude both the two virgin soils and Kirstenbosch No. 3, which has a C/N ratio of 22·9 : 1, the average C/N ratio becomes 14·7 : 1. We are thus justified in regarding the C/N ratio of the winter rainfall region soils (cultivated) of the South-West Cape as being of the order of 15 : 1, and thus decidedly above the 10–12 : 1 level. This conclusion is further strengthened when we come to consider the average C/N ratio of the subsoils. Excluding the low level soil sample of Kirstenbosch No. 3, the average of the six subsoils studied is 14·7 : 1. Even if in addition to the low level sample of Kirstenbosch No. 3 we exclude the subsoil of Kirstenbosch No. 1, which is virgin and has a C/N ratio of 22·6 : 1, we still have an average C/N ratio of 13·2 : 1.

The depth to which soil samples were taken varied with the character of the soil profile. Below will be found the average organic matter contents and C/N ratios for the soils, grouped on the basis of depth of sampling. Kirstenbosch No. 1 and Bredasdorp No. 1 are not included in the series. These are both surface soils and are virgin, and Bredasdorp No. 1 has the very unusually high organic matter content of 21·25 per cent.

The number of samples is too small to demonstrate any correlation between depth of sampling, organic matter content, and C/N ratio, except that we can perhaps regard the low average C/N ratio of 13·6 : 1 for the

two "Bizweni" soils as being partly due to the depth range of 0–3 feet for the soil samples.

Depth of sampling.	No. of soils in group.	Organic matter, per cent.	C/N ratio.
0–1 foot*	6	3·13	16·4 : 1
0–18 inches	1	1·45	14·5 : 1
0–2 feet	1	2·17	16·1 : 1
0–3 feet	2	1·985	13·6 : 1

In the case of six profiles showing a differentiation into distinct soil and subsoil layers (A and B horizons), determinations of carbon and nitrogen, and by calculation of organic matter (C × 1·724) and of C/N ratios, were made of both soil and subsoil. Except for the soil from Krom River Farm, there was a decided decrease in organic carbon and in nitrogen in passing from soil to subsoil, and since the organic carbon showed a more pronounced decrease than the nitrogen, there was a very decided narrowing of the C/N ratio. The relevant data are presented below:

	C/N ratio of soil.	C/N ratio of subsoil.	Per cent. decrease.
Kirstenbosch No. 1 . .	26·9 : 1	22·6 : 1	16
Dwaarsriviers Hoek No. 2 .	15·2 : 1	12·8 : 1	15·8
"Glen Elgin" . . .	17·1 : 1	14·3 : 1	16·4
Dwaarsriviers Hoek No. 3 .	14·5 : 1	10·7 : 1	26·2
Dwaarsriviers Hoek No. 1 .	16·1 : 1	12·3 : 1	23·6

The subsoil in the case of Krom River Farm shows only a small decrease in organic carbon as compared with the soil (a decrease of 5·6 per cent.), and the C/N ratio shows a slight widening—a widening of only 2·6 per cent., which is of very doubtful significance. To what extent this narrowing of the C/N ratio is related to the differentiation of subsoil from soil and to what extent it is merely related to increasing depth is uncertain. The subsoils above are arranged in increasing order of depth, and it will be seen that there are indications of depth effects, the more deeply situated subsoils showing a greater percentage decrease of C/N ratio. In this connection Kirstenbosch No. 3 is of interest, since to a depth of over 4 feet—when the

* The 0–1-foot group contains soils sampled to a depth of 0–9 inches.

water table was reached—there was no morphological differentiation into soil and subsoil, and in this case there was no narrowing of C/N ratio with depth. In fact the C/N ratio of soil from a depth of 27–36 inches was 12·2 per cent. higher than the C/N ratio of the soil from the surface to a depth of 9 inches. As in the case of Krom River Farm subsoil, however, the decrease in organic carbon with increase in depth is very slight, being only 1·25 per cent.

Taken as a whole, it would seem that the narrowing of the C/N ratio with depth is to be regarded as a corollary to the general theorem that the C/N ratio tends to narrow with a decreasing organic matter content in the soil. Certainly the soils studied during this investigation show within the various locality groups a close correlation between organic matter content and C/N ratio. Kirstenbosch No. 4 presents the only exception to this rule. The subsoils show the same relationship between total organic matter and C/N ratio, with a slight discrepancy between Dwaarsriviers Hoek No. 1 and Dwaarsriviers Hoek No. 2.

It is only necessary here to draw attention to one other point. Most of the soils dealt with are cultivated, but Kirstenbosch No. 1 and Bredasdorp No. 1 are virgin, and have the highest organic matter contents, the last having a very high organic matter content indeed, in spite of its being in the district of lowest annual precipitation from which soils were collected. The widest C/N ratios are shown by Kirstenbosch No. 1 and Kirstenbosch No. 3, and especially the former. Bredasdorp No. 1, together with "Glen Elgin," show the next highest C/N ratios. Thus, on the whole, the results obtained bear out the general conclusion that virgin soils show both higher organic matter contents and wider C/N ratios than cultivated soils.

Summary.

1. No previous investigation of this type has been carried out in South Africa.

2. Soil nitrogen was determined by the Kjeldahl method, soil organic carbon by the sulphur dioxide reduction method of Robinson, and organic matter by C × 1·724.

3. Robinson's wet combustion method was found to give very satisfactory agreement between duplicates.

4. The estimation of soil organic matter by the formula N × 20 is shown to be entirely unsuitable for the soils investigated.

5. The C/N ratios of the soils studied range from 11·2 : 1 to 22·9 : 1, with an average for the twelve soils of 16·6 : 1.

6. Evidence is presented for regarding the C/N ratio of the winter rainfall region soils (cultivated) of the South-West Cape as being of the order of 15 : 1.

7. Within a rainfall locality the C/N ratio widens with increasing organic matter content.

8. In passing from soil to subsoil, with one exception (Krom River Farm), there is a marked decrease of organic carbon and nitrogen and thus of organic matter, and this is accompanied by a narrowing of the C/N ratio.

9. The organic matter content of Krom River Farm is practically the same for both soil and subsoil, and the C/N ratio shows a widening of 2·6 per cent. in the subsoil.

10. The average C/N ratio of the six subsoils studied is 14·7 : 1, or, excluding Kirstenbosch No. 1, the C/N ratio becomes 13·2 : 1.

11. Analyses were made for soil at both a high (0–9 inches) and a low (27–36 inches) level in the case of Kirstenbosch No. 3. At the lower level the organic carbon was estimated as 1·25 per cent. lower, and the C/N ratio 12·2 per cent. higher, compared with the surface soil.

12. On the whole, the organic matter content and the C/N ratio of the cultivated soils are lower than those of the virgin soils.

13. Bredasdorp No. 1 is a remarkable virgin soil, having an organic matter content of 21·25 per cent., although this locality has the lowest rainfall of all the localities from which soil samples were collected.

14. No correlation was found between the average organic matter content and C/N ratios of the soil groups and the average annual rainfall. This is not surprising when the heterogeneous character of the soils studied is considered.

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VELD-BURNING EXPERIMENTS AT OAKDALE, RIVERSDALE.

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(With Plates VI–IX and a Diagram.)

(Read April 17, 1935.)

Introduction.

The plant community termed rhenosterveld is characteristic of fine-grained soils in the south-western coastal belt. This type of vegetation is only too familiar in these regions, and the general opinion among botanists, partly supported by experimental evidence, is that this is not a natural community but one induced by man's interference, chiefly by the prevalent habit of veld-burning. It is therefore important to gain as detailed a knowledge as possible of the behaviour of this type of plant community, under conditions which may be controlled by man, in the different climatic zones in which the rhenoster bush (*Elytropappus rhinocerotis*) exhibits its well-known aggressive tendencies.

In two previous publications (2, 4) the writer has recorded observations and experiments on veld-burning in rhenosterveld, at Cape Town and Stellenbosch, both localities with a fairly high rainfall, and the results in the two cases were similar. In these places rhenosterveld, when fully developed, is a closed type of plant community with the spaces between the bushes shaded by their interlacing branches. Under these conditions it was found that the rhenoster bush was incapable of reproducing itself by seed, and only after burning were seedlings present in large numbers. The seedlings grew rapidly, and a year after burning rhenosterveld had re-established itself.

Just as the experiments at Stellenbosch were nearing completion, Mr. J. F. Burger, at that time Principal of the Oakdale Agricultural School, wrote to me about the spread of the rhenoster bush in the Riversdale district. As a result of a visit to Riversdale in 1929 I decided to co-operate with Mr. Burger in conducting some experiments on veld-burning on much the same lines as at Stellenbosch. Unfortunately for our plans, Mr. Burger was transferred from the Oakdale Agricultural School in 1930, but I am

grateful for his assistance in the initial stages of the work. Without his help it would have been impossible to carry out this research. He was responsible for fencing, laying out the plots, and burning and clearing at given times.

The previous experiments on veld-burning in rhenosterveld had been carried out in places with a rainfall (25 inches a year or more) nearly all of which fell during the winter months. At Riversdale climatic conditions are rather different. The annual rainfall is considerably lower (17·18 inches) (3) and its incidence is fairly evenly distributed over the months of the year. The district is subject to periodic hot, dry winds, usually known as berg winds (5), and these have a deleterious effect on the vegetation. It is therefore not surprising to find that the rhenosterveld found in the Riversdale district is of a much more open type than that found near Cape Town and Stellenbosch. The bushes are seldom more than three feet in height, usually less, and are spaced farther apart so that their branches do not interlace to any marked extent. The uniform shading of the ground noted at Stellenbosch is consequently not present here.

The results of the experiments about to be recorded differ in many respects from those recorded earlier (2, 4), and these differences appear to be correlated with the less favourable climatic conditions in the Riversdale district. A comparison of the results in the areas studied will be given at the end of the paper.

Experiments at Riversdale.

The plots selected for these experiments were situated in ground belonging to the Oakdale Agricultural School and had been used by the school for sheep grazing. The area was covered with typical rhenosterveld which had suffered from successive burnings (fig. 1), but the site selected had escaped fire for some years and the rhenoster bushes were well grown. The plots were situated on top of a ridge composed of rather fine-grained rocks belonging to the Witteberg Series (5). The soil produced by these rocks varied from neutral to slightly alkaline, judged from results obtained with the use of colour indicators. The altitude was a little over 300 feet. The general plan of the experimental plots is shown in the accompanying diagram.

During a visit made in November 1929 the plots were mapped out and the whole area fenced. A general survey of the plant population was made. In order to do this several quadrats with sides measuring 4 feet were laid down at random on each of the four plots and careful lists of the plants made. In this way a good idea of the relative numbers of the different plants was obtained. A complete list of plants growing on the area is given at the end of this paper (p. 239).

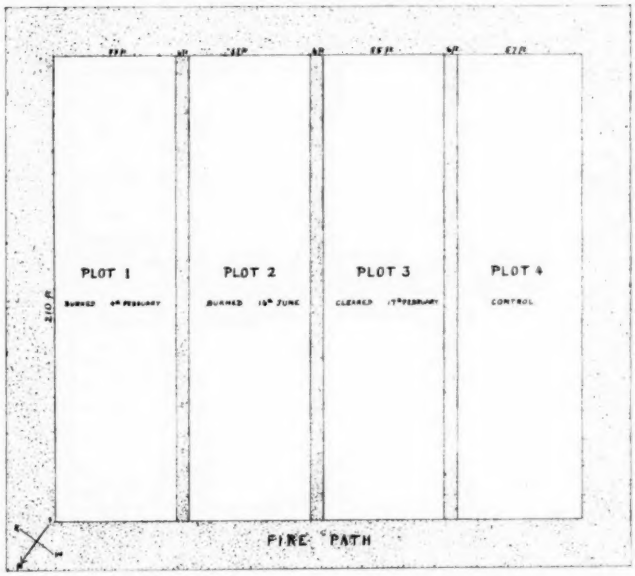

Diagram of the experimental plots at Riversdale.

The largest plant on the area was *Aloe ferox*, plants of which were scattered about like sentinels among the rhenoster bushes (fig. 1). The following list gives the principal shrubs, 2–3 feet in height, and their relative frequencies :—

Elytropappus rhinocerotis (rhenoster bush) a.
Aspalathus spinosa f.
Selago fruticulosa f.
Relhania genistaefolia o.
Asparagus capensis o.
Aspalathus microdon o.
Indigofera denudata o.
Barosma foetidissima o.
Eriocephalus umbellulatus o.
Mundia spinosa r.
Euclea undulata r.

The rhenoster bush far outnumbered any of the other shrubs which were scattered about here and there in the grey-green matrix of the rhenoster bush. In a previous publication (1) it was pointed out that two distinct forms of the rhenoster bush may be recognised. One is the characteristic plant of Signal Hill, Cape Town, and the other the common plant in the Stellenbosch area. At Riversdale both forms were present, but the Signal Hill form was the more common. The bushes were well grown and vigorous, though here and there dead bushes were noted. One striking difference between this type of rhenosterveld and the type previously investigated

lay in the presence of some young plants and seedlings. In the previous examples these had been strikingly absent, and the obvious conclusion was drawn that rhenosterveld must be a stage in succession and not a climax community. Here at Riversdale the presence of young plants among the old shows that this community may be a relatively stable one under existing conditions. It is possible that rhenosterveld in this district may be a climax community. However, this region is one where veld-burning has been practised extensively, and it is probably better to regard this type of vegetation as a subclimax—that is, a stage in development where the vegetation is held in check more or less permanently by artificial factors.

Aspalathus spinosa and *Selago fruticulosa* were frequent, but in both cases a very high proportion of the plants were dead or dying. A few seedlings of both plants, however, were present. The remaining shrubs were not abundant, and their seedlings appeared to be rare or absent.

In addition to the shrubs mentioned above there were numerous smaller plants, both woody and herbaceous, and these are listed below. They were scattered about here and there, none of them being particularly abundant.

Aristida vestita.
Athanasia dimorpha.
Blepharis molluginifolia.
Crassula sp.
Chrysocoma tenuifolia.
Cymbopogon marginatus.
Drosanthemum calycinum.
Ehrharta calycina.
Helichrysum ericaefolium.
H. erosum.
H. excisum.
Hermannia flammea.
H. saccifera.
Hibiscus pusillus.
Lightfootia tenella.
Lobostemon echioides.
Mesembrianthemum sp.
Pelargonium rustii.
Polygala sp.
Restio cuspidatus.
Selago corymbosa.
Ursinia discolor.

A plant that was listed as rare was *Falkia dichondroides*, an inconspicuous creeping plant whose subsequent behaviour was striking. Remains of various annuals were evident, but most of these were not in a suitable condition for correct determination, and consequently annuals have been omitted from the lists.

Plot 1 was burned on 4th February and Plot 2 on 16th June 1930, Plot 3 was cleared on 17th February. The process of clearing was not done very thoroughly and numerous small plants, including young rhenoster bushes, remained untouched. Plot 4 was left to serve as a control. It may be stated here that to-day, five years since the experiments were started, this plot shows no appreciable change in its population.

1930.—The next visit was paid in October 1930. A group of Aloes on Plot 1 survived the fire, these being the only plants to suffer no damage to their aerial parts as a result of burning. The difference between the plot

burned in summer and that burned in winter was slight. In the former case new growths were slightly more luxuriant than in the latter, but no important differences manifested themselves. This similarity was maintained throughout the investigation, and it is therefore unnecessary to consider the time of burning as a factor of any importance in this case. The most striking feature of the burnt areas at this time was the abundance of *Falkia dichondroides* (fig. 2). This plant, hitherto recorded as being rare, was now the most conspicuous plant, as will be seen in fig. 2. *Pelargonium myrrhifolium*, the presence of which had not been observed in 1929, was abundant and may be seen in flower in the photograph. *P. myrrhifolium* behaved in the same way at Stellenbosch. This vigorous response to burning seems to be a feature of several Pelargoniums. The most conspicuous seedlings present were two species of *Selago*, *S. corymbosa* and *S. fruticulosa*. Other plants of which seedlings were identified were

Aspalathus spinosa.
Elytropappus rhinocerotis.
Hermannia flammea.
H. saccifera.

These, however, were small and their presence only detected after careful search.

The following were being regenerated by shoots from underground stocks:—

Asparagus capensis.
Hibiscus pusillus.
Lobostemon echioides.

Three members of the Acanthaceae, a family noteworthy for its absence or scarcity in the south-western flora, were flourishing on the burnt areas. These were *Blepharis molluginifolia*, *Ruellia zeyheri* (fig. 3), and *Barleria pungens*.

On the cleared area the rhenoster seedlings and young plants that had been left in the ground were growing rapidly. Grasses were more abundant here than on the burnt areas, and in this respect the observations made here agree with those made at Stellenbosch. Most of the plants that were conspicuous on the burnt areas, notably *Falkia dichondroides*, *Selago corymbosa*, and *Selago fruticulosa*, were present but did not occupy the prominent position noted on the burnt plots.

1931.—Two visits were paid in 1931, one in July and the other in October. Owing to the desirability of comparing the vegetation at the same season in each year, the October records are the ones made use of here.

The whole aspect of the burnt areas had changed. The most striking

plant was now *Selago corymbosa*, which was abundant and in full flower (fig. 4). *Selago fruticulosa* was frequent but its inconspicuous flowers rendered it less noticeable. *Falkia dichondroides* and *Pelargonium myrrhifolium* were still frequent but much less abundant than in the previous year. Seedlings of *Aspalathus spinosa* were much in evidence but too young for flowering. *Aspalathus microdon* was in approximately the same stage of development but much less conspicuous. *Hermannia saccifera* was abundant, having regenerated from old stock. Seedlings of the rhenoster bush were still small and occupied a subordinate position among the plants now covering the area.

On the cleared area the rhenoster bushes were fairly large. Grasses were still abundant, while the characteristic plants of the burnt areas were poorly represented (fig. 5).

1932.—A further visit was paid in October 1932. Once more the aspect of the burnt areas had changed. On this occasion *Aspalathus spinosa* was the dominant plant, forming a dense and extremely prickly covering. Unfortunately the photograph taken to show the general appearance of the burnt plots was not successful, but fig. 6, taken of a similar stage just outside the experimental area, gives a good idea of the tangled growth of these bushes. Next in prominence was *Aspalathus microdon*, the bushes of which were scattered about among the slightly larger bushes of *Aspalathus spinosa*. *Selago corymbosa* and *Selago fruticulosa*, the two dominating plants of the previous year, were now quite inconspicuous, and many dead and dying plants of these species were noted. *Falkia dichondroides* was still present but was dying off rapidly. Seedlings of the rhenoster bush were from 8 to 10 inches high, growing in amongst the *Aspalathus*. In its young stages the rhenoster bush has a stiff, upright habit of growth. This and its smaller size make it inconspicuous in this stage of succession, but a careful examination of the area showed that the young plants were there growing steadily if slowly.

On the cleared plot the two species of *Aspalathus* were present but not conspicuous, while the rhenoster bushes were larger than the *Aspalathus*. Grasses were still a noticeable feature of this plot.

1934.—It was unfortunately impossible to visit Riversdale in 1933 and the next observations were made in October 1934. On this occasion the conspicuous plant was *Aspalathus microdon* which two years previously had occupied a subsidiary position to *Aspalathus spinosa* (fig. 7). Now the positions were reversed, and *A. spinosa* showed clear signs of senescence. Of the other plants which had been outstanding in previous years, *Falkia dichondroides* had disappeared completely, only one plant of *Pelargonium myrrhifolium* was observed, nearly all plants of *Selago fruticulosa* were dead, and only odd plants of *Selago corymbosa* were noted. On the other hand

the rhenoster bushes were as tall as the *Aspalathus* bushes and quite easily seen by even a casual observer (fig. 8). It was clear that this shrub was well on its way to assuming the dominant rôle it had played in the vegetation at the beginning of the experiment.

On the cleared plot the rhenoster bushes were slightly larger than on the burnt plots and they were the most conspicuous bushes. *Aspalathus microdon* was present but occupied a minor position. Grasses, as on previous occasions, were more prominent on this plot than elsewhere.

General Remarks.

The experiments detailed above have extended over five years and the effects of burning may be summed up as follows:—

Before burning.

November 1929. Whole area occupied by rhenosterveld.

After burning.

October 1930. Initial stage in succession (*Falkia-Pelargonium* stage).

October 1931. Second stage in succession (*Selago* stage).

October 1932. Third stage in succession (*Aspalathus spinosa* stage).

October 1934. Fourth stage in succession (*Aspalathus microdon* stage).

In each year certain plants assumed a position of dominance, then gradually sank back into obscurity as they were ousted by their more successful rivals. From a study of rhenosterveld generally in the Riversdale area it seems certain that after a short period *Aspalathus microdon* would lose its supremacy and the rhenoster bush would once more assume dominance, so that the fifth stage would be rhenosterveld.

Comparison with Rhenosterveld at Stellenbosch.

We are now in a position to compare the reactions to burning of the two types of rhenosterveld : (i) the mesophytic type of Stellenbosch, and (ii) the more xerophytic type of Riversdale.

In the Stellenbosch type burning leads to an immediate return of rhenosterveld. Seedlings of the rhenoster bush are extremely sensitive to drought (1), and the very damp winter months of that district (see the accompanying table) are evidently favourable to their establishment and growth. In one of the permanent quadrats (area 16 square feet) 694 seedlings were recorded about nine months after burning had taken place. A large number of these survived the first year, and at no time in the process of renewing the vegetal covering did any plant dispute the supremacy of the rhenoster bush.

TABLE.

	Riversdale.	No. of rainy days.	Stellenbosch.	No. of rainy days.
Jan. . .	1·14	4	0·80	2
Feb. . .	1·30	5	0·55	2
Mar. . .	1·75	6	0·92	4
Apr. . .	1·70	6	2·24	7
May . .	1·52	6	4·18	9
June . .	1·43	6	4·92	11
July . .	1·19	6	4·03	10
Aug. . .	1·41	6	3·83	9
Sept. . .	1·56	6	2·73	9
Oct. . .	1·59	6	2·20	7
Nov. . .	1·37	5	1·39	5
Dec. . .	1·22	4	0·78	4
Totals .	17·18	66	28·57	79

Rainfall given in inches.
Figures obtained from "Rainfall Normals up to the end of 1925," by A. D. Lewis, M.A., M.Inst.C.E., Cape Times Ltd., 1927.

At Riversdale the case is very different. The total annual rainfall is considerably less and the rain is distributed in such a way that at no month in the year would the ground be consistently damp (see table where the number of rainy days in each month is given). Such conditions would not be favourable to the establishment of the rhenoster seedlings with their water-demanding habits, and it is therefore not a surprising fact that the highest number of rhenoster seedlings noted in any quadrat on the burnt areas (these quadrats being the same size as those at Stellenbosch) was 11. This number, when compared with the corresponding 694 for the Stellenbosch area, is significant.

At Stellenbosch, where the average number of rhenoster bushes on the quadrats at the beginning of the experiments was 14 and where 39 was the maximum number noted on any untouched quadrat, competition among the rhenoster seedlings following on burning must be very severe. At Riversdale the rhenoster seedlings seem to be more or less free from this internecine strife. Here their competitors are unrelated plants, and for several years these latter plants appear to have the upper hand. Before rhenosterveld is once more established there is a series of successional changes distributed over several years.

None of the characteristic plants of these stages in succession has any value for grazing purposes. In fact, every one of them is just as useless if not more so than the rhenoster bush, which at any rate does provide the poorer members of the population with brushwood for their fires. The few grasses and young growths which appear after burning in no way compensate for losses in humus and soil moisture which are the direct results of burning.

Part of the expenses incurred in this work were defrayed by a grant from the Research Grant Board, and I take this opportunity of expressing my thanks. My thanks are also due to my husband whose assistance in the field has been invaluable. I also wish to express my appreciation of the facilities afforded me by the Oakdale Agricultural School.

Summary.

1. Experiments in burning and clearing rhenosterveld at Riversdale have been carried out.

2. The results of burning differ from those obtained in rhenosterveld at Stellenbosch where an immediate return to rhenosterveld was demonstrated. Here the vegetation undergoes a series of successional changes and it takes several years for rhenosterveld to be established once more.

3. The results of clearing are similar to those obtained at Stellenbosch. Grasses appear in greater abundance than usual. The successional changes noted after burning are not apparent in this case.

4. Comparison is made between the results of these experiments and those made some years ago at Stellenbosch.

List of Plants on the Experimental Plots at Oakdale, Riversdale.

Note.—The figure given after each species is the reference number of specimens preserved in the herbarium in the Botanical Department of the University of Cape Town.

Pteridophyta.

Ophioglossum nudicaule L.f. 3550.

Gramineae.

Aristida vestita Thunb. 2873.
A. angustata Stapf. 2714.
Brachiaria serrata Stapf. 3494.
Brizopyrum capense Trin. 3497.
Cymbopogon marginatus Stapf. 2658.
Cynodon dactylon Pers.
Danthonia stricta Schrad. 4817.
Digitaria eriantha Steud. 3496.
Ehrharta calycina Sm. 3140.

Gramineae—*contd.*

E. capensis Thunb. 3147.
Eragrostis curvula Nees. 3495.
E. nebulosa Stapf. 2711.
E. obtusa Munro. 2713.
Lasiochloa longifolia Kunth. 4182.
Pentaschistis airoides Stapf. 3165.
Themeda triandra Forsk. 3493.

Cyperaceae.

Ficinia tristachya Nees. 3501.
F. setiformis Schrad. 3540.

Restionaceae.

Restio cuspidatus Thunb. 4818.

Liliaceae.

Aloe ferox L.f.
Asparagus capensis L. 3542.
A. sp.
Bulbine narcissifolia Salm.-Dyck. 3139.

Amaryllidaceae.

Hypoxis floccosa Baker. 3154.

Iridaceae.

Geissorhiza patersoniae L. Bolus. 3152.

Haemodoraceae.

Cyanella capensis L. 3512.
C. lutea L. 3513.

Santalaceae.

Thesium sp. 4811.

Chenopodiaceae.

Atriplex semi-baccata R. Br. 2709.
Chenopodium vulvaria L. 3492.

Aizoaceae.

Drosanthemum calycinum L. Bolus. 3508.
Galenia secunda Sond. 3162.
Mesembrianthemum sp.
Pharnaceum incanum L. 3504.
Ruschia bellidiflora L. Bolus.

Caryophyllaceae.

Corrigiola telephifolia Poir. 3163.
Dianthus incurvus Thunb. 2858.

Crassulaceae.

Crassula campestris E. and Z. 3161.
C. sp.

Leguminosae.

Aspalathus microdon Benth. 4809.
A. spinosa L. 4184.
Indigofera denudata Thunb. 3158.
Lessertia linearis DC. 4183.
Tephrosia capensis Pers. 3155.
Wiborgia tetraptera E. Mey. 3498.

Geraniaceae.

Pelargonium myrrhifolium Ait. 3168.
P. rustii R. Knuth. 3143.
P. scabrum L'Her. 3517.

Oxalidaceae.

Oxalis spp.

Rutaceae.

Barosma foetidissima B. and W. 3552.

Polygalaceae.

Mundia spinosa DC. 3541.
Muraltia trinervia DC. 4812.
Polygala pubiflora Burch. 3518.

Euphorbiaceae.

Euphorbia pistaefolia Bois. 3499.

Anacardiaceae.

Rhus lucida L.

Malvaceae.

Hibiscus pusillus Thunb. 2870.

Sterculiaceae.

Hermannia alnifolia L. 3553.
H. candicans Ait. 3142.
H. decumbens Willd. 3500.
H. flammea Jacq. 3149.
H. saccifera Turcz.

Thymelaeaceae.

Gnidia parvula Wolley Dod. 2876.
G. (= *Arthrosolen laxus* E. Mey). 3506.

Ebenaceae.

Euclea undulata Thunb.

Gentianaceae.

Sebaea schizostigma Gilg. 3157.

Asclepiadaceae.

Asclepias rotundifolia Mill.
Schizoglossum aschersonianum Schlechter. 4813.
Stapelia sp.

Convolvulaceae.

Cuscuta appendiculata Engelm. 2656.
Falkia dichondroides Baker. 3167.

Boraginaceae.

Lobostemon echioides Lehm. 3505.

Labiatae.

Teucrium africanum Thunb. 3151.

Acanthaceae.

Barleria pungens L.f. 2864.
Blepharis molluginifolia Pers. 2865.
Ruellia zeyheri T. Anders. 2866.

Scrophulariaceae.

Diascia nemophiloides Benth. 3159.
Phyllopodium diffusum Benth. 3164.
Sutera antirrhinoides Hiern. 3160.
S. linifolia O. Kuntze. 3547.

Selagineae.

Selago corymbosa L. 3510.
S. fruticosa L. 3502.
S. fruticulosa Rolfe. 2851.

Campanulaceae.

Lightfootia tenella A. DC. 2867.
Lobelia erinus L.

Compositae.

Athanasia dimorpha DC. 2857.
A. filiformis L.f. 2681.
A. linifolia Harv. 2680.
Chrysanthemum carnosulum DC. 4186.
Chrysocoma tenuifolia Berg. 3051.
Cotula sororia DC. 3150.

Compositae—*contd.*

Cryptostemma calendulacea R.Br. 4136.
Dicoma spinosa Druce. 3047.
Elytropappus rhinocerotis Less. 3071 and 3072.
Eriocephalus umbellulatus Less. 3551.
Gazania pinnata Less. 3514.
Helichrysum ericaefolium Less. 2850.
H. excisum Less. 2849.
H. parviflorum DC. 2869.
H. erosum Harv. 3515.
Ifloga polycnemoides Fenzl. 3153.
Leontonyx glomeratus DC. 3503.
Oligocarpus calendulaceus Less. 3169.
Othonna sp.
Relhania cuneata Thunb. 2861.
R. genistaefolia L'Her. 2654.
R. sessiliflora Thunb. 4181.
Stoebe rugulosa Harv. 4815.
Ursinia anthemoides R. Br. 3516.
U. discolor Less. 3543.

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FIG. 1.—General view of rhenosterveld at Oakdale, showing the scars of successive burnings.

FIG. 2.—1930. Plot 1. Showing presence of *Falkia dichondroides* and *Pelargonium myrrhifolium* (in flower). Young plants of *Selago corymbosa* are conspicuous.

Margaret R. Levyns. *Neill & Co., Ltd.*

Fig. 3.—*Ruellia zeyheri.*

Fig. 4.—1931. Plot 1. Showing abundance of *Selago corymbosa.*

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Fig. 5.—1931. Plot 3. *Selago corymbosa* is present but not specially abundant.

Fig. 6.—*Aspalathus spinosa* stage.

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FIG. 7.—1934. Plot 1. *Aspalathus microdon* stage.

FIG. 8.—1934. Detailed view of characteristic plants on Plot 1. *Elytropappus rhinocerotis*, *Aspalathus microdon*, *Selago fruticulosa* (dying), *Aspalathus spinosa* (dead).

Margaret R. Levyns. *Neill & Co., Ltd.*

THE ORGANIC MATTER CONTENT AND CARBON-NITROGEN RATIOS OF SOME SEMI-ARID SOILS OF THE CAPE PROVINCE.

By W. E. Isaac and B. Gershill.

(Communicated by R. S. Adamson.)

(With one Text-figure.)

(Read May 15, 1935.)

In a previous paper (Isaac, 1935) the organic matter content and C/N ratio of a number of soils from the winter rainfall region of the Cape Province

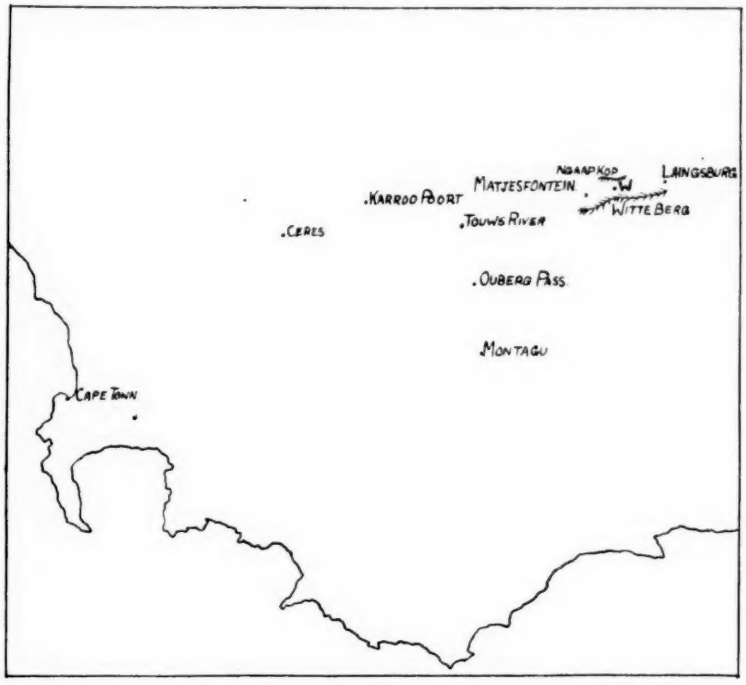

Fig. 1. (W. is Whitehill.)

were recorded and evidence was presented for regarding 15 : 1 as the characteristic order of C/N ratio for cultivated soils of the region. During the course of 1933 and 1934 a few soils were collected from semi-arid regions of the Cape Province, and it seemed profitable to study a number of these as a contrast to the previous series.

The soils dealt with in this paper are virgin, although in the case of soils of very stony texture with a sparse vegetative cover, the differences shown by virgin and cultivated soils in regard to C/N ratio and even organic matter content are probably never great. The localities from which the soils were collected are shown in fig. 1, and are included in regions of 5–10 inches of rainfall per annum. Local variations in humidity factors are associated with topographical features, and these are certainly significant in the case of Whitehill district. Further, as these localities are situated in the western part of the Karroo complex of semi-arid lands, the rain mostly falls during the winter months.

The soils are mostly of a very light brown colour, generally alkaline in reaction and not infrequently decidedly brackish. Perhaps the most common and characteristic features are their shallowness and stoniness. A depth of 6 inches was found to be exceptional, and in some cases even this top soil consists predominantly of stones (*e.g.* soil over the white gypsum band on the south slope of Ngaap Kop, Whitehill).

Methods.

Collection and Preparation of Soil Samples for Analysis.—The very stony character of the soil made the use of a borer impossible. A number of diggings were made, and the soil thus obtained was thoroughly mixed and quartered until a sample of about 10–15 lb. was obtained. Some of this was used for p_H determinations and then the bulk was laid out to dry. The air-dry soil was passed through a 2-mm. sieve and stored for analysis. The carbon and nitrogen determinations were carried out with soil portions ground to pass a 90-mesh sieve.

With one exception, diggings were made to a depth of 3–4 inches, since below this depth the profile becomes very stony and outcrops of rock are frequent. In the case of Baviaans river alluvial soil, two samples were made at different depth levels. (See p. 249.)

Hydrogen-ion Concentration.—These determinations were carried out in the field, using a B.D.H. capillator set.

Nitrogen Estimation.—The digestion was carried out according to the Official and Tentative Methods of the A.O.A.C. (Washington, 1930), using the Gunning-Hibbard digestion mixture. After complete decomposition the flasks were cooled and the contents diluted with water. They were

then corked and allowed to stand overnight. The solution was subsequently transferred to the distillation flasks, the sandy residue being thoroughly washed by decantation. After adding excess of 40 per cent. NaOH solution the ammonia was distilled into 4 per cent. boric acid solution and directly titrated to a standard end-point, the indicator being bromophenol-blue. The standard end-point was obtained by running blanks, which were titrated in the same way, and the end-points of the actual determinations matched to that of the blanks. Corrections for blank values were made.*

Organic Carbon.—The sulphur dioxide reduction method of Robinson, McLean, and Williams (1929) was employed.

Organic Matter.—C × 1·724. For a fuller consideration of these methods see previous paper dealing with the C/N ratio and organic matter content of soils of the winter rainfall area. (Isaac, 1935.)

Moisture.—This was determined on a 10-gm. sample of air-dry soil heated to constant weight at 105° C. All calculations were made on an oven-dry weight basis.

Experimental.

The soils analysed can be grouped as follows:—

1. Whitehill (Western Karroo) . . . . 4 soils.
2. Karroo Poort (Western Karroo) . . . . 1 soil.
3. Ouberg Pass † . . . . . 1 soil.

Whitehill.‡—Whitehill is situated on a plain of approximately 3000 feet altitude, which slopes gently downwards from the Wittebergen (altitude 5000 feet) in the south, towards the Ngaap Kop in the north. Between the plain and the mountains in the north there is a group of foothills. At the lowest level of this sloping plain the Baviaans River runs parallel to the mountain ranges, and into this river (dry for the greater part of the year) run a number of tributaries flowing northwards from the Wittebergen.

The soils of the plain overlie Dwyka shales and conglomerate with large quartzite inclusions. To the south the Wittebergen are composed of quartzite rocks, and to the north the Dwyka give way to the Ecca series, of which Ngaap Kop is built. The junction of these two series is marked by a white band of gypsum shale. (Compton, 1929.)

* This method is a modification of that proposed by Scales and Harrison (1920).

† The name Ouberg Pass is not to be found in the maps of the district, but it is the name given by the inhabitants of the region to Nauga's Poort in Nauga's Hills, which are a part of the Wageboombergen.

‡ Whitehill consists of a railway siding, two houses and a small Botanic Garden, which is a branch of the National Botanic Gardens of S. Africa, centred at Kirstenbosch, N. Cape Peninsula.

The average annual rainfall is 5·07 inches,* most of which usually falls between May and August These rainfall figures apply to the plain more particularly in the region of the station and the Baviaans River. On the Wittebergen the available moisture is greater since there are frequent clouds and mists on these mountains, especially in winter.†

The plain between the mountain masses is covered by an open shrubby vegetation. Among the shrubs there are a number of succulents and herbaceous plants, the latter with leaves adpressed against the soil and with relatively large underground storage organs. Most prominent among the succulents, largely on account of its size but also on account of its frequency, is *Cotyledon Wallichii*. The larger succulents, however, occur most commonly in the damper kloofs leading up to the Wittebergen, and also in the kloofs on the slopes on Ngaap Kop and its foothills. One feature worthy of special attention in regard to the smaller succulents is their inconspicuousness when not in flower. The most prominent bush species are *Mesembryanthemum spinosum*, *Chrysocoma tenuifolia*, *Pteronia* (especially *P. Foleyi*), and on disturbed ground *Galenia africana*. All of these species are very common and taken together form dominants. *M. spinosum* covers large tracks to the practical exclusion of all else. These areas are perhaps a little depressed and the soil tends to be somewhat deeper.

Along the banks of the Baviaans River there is a fringe of trees, the commonest species being *Rhus lancea*. *Acacia karroo* and *Royena pallens* are also prominent. On the flat alluvial land and farther away from the banks there are a number of halophytic species. The largest and commonest of these is *Salsola aphylla*. *Cryophytum crystallinum* is also a prominent plant in this habitat, also *Drosanthemum* spp.

As we ascend the Wittebergen the Karroid vegetation disappears, and first *Elytropappus* (Rhenoster bush) and then vegetation of the characteristic winter rainfall type makes its appearance. The transition zone is dominated by *Elytropappus* and *Passerina glomerata*. Of the "Cape species" the largest is *Protea marginata*. We also find a number of Restionaceae, a number of Ericas and *Leucadendron*.

The soils of the district are light brown or even greyish in colour, very shallow and stony. Generally the soil barely extends to a depth of four inches, and below that level we come to a horizon consisting essentially of sintered rock. In the case of the Wittebergen there is no continuous

* The rainfall records were obtained from the station at Whitehill. The available records extend from 1923 to time of visit (July 1934). The average quoted was obtained from the figures for 1923–5, 1929–31 and 1933. The figures for 1926–28 and for 1932 were rejected as of doubtful value. This view was arrived at due to bad entries, wrong totals, etc.

† This statement is made on the authority of Professor R. S. Adamson.

cover of soil, the hard rock being exposed. The rock does not splinter, but cracks are frequent. In these, pockets of soil (often quite deep) are formed. The soils were found to have a p_H on the alkaline side of neutrality. (A range of from p_H 7·0 to 7·4.) Sometimes the soils are a little below p_H 7·0, and soil from the Wittebergen was found to be decidedly on the acid side of neutrality.

The soil samples analysed are as follows:—

Whitehill No. 1.—On the plain: *Mesembryanthemum spinosum* dominant. p_H 7·0.

Whitehill No. 2.—On the plain, within the confines of the Botanic Garden. Soil under *Cheiridopsis cigarettifera.** p_H 6·8.

Whitehill No. 3.—Alluvial deposit, Baviaans River.

Salsola aphylla dominant. Profile: Upper layer of fine sandy soil. Depth varies from about 6 to 15 inches. Then follows a series of gravel and narrow silt beds to a depth of 3 to 4 feet from the surface. This is followed by a second layer of sandy soil extending to a depth of about 9 inches. Patches of gravel intrude into this second soil layer. Two sets of samples were taken:

(*a*) 0 to 6 inches.

(*b*) Second soil layer to depth of about 6 inches. p_H determinations: (*a*) 7·4; (*b*) 7·0.

Whitehill No. 4.—On north facing side of the Wittebergen under Cape vegetation, chiefly *Protea marginata*. p_H 6·4.

The carbon nitrogen, C/N ratio and organic matter values for these soils are given below in Table I.

TABLE I.

Soil.	Organic Carbon, per cent.	Nitrogen, per cent.	C/N ratio.	Organic Matter, C × 1·724.
Whitehill No. 1 .	0·692	0·051	13·5 : 1	1·19
Whitehill No. 2 .	0·408	0·042	9·7 : 1	0·703
Whitehill No. 3—				
(*a*) High Level .	0·434	0·052	8·3 : 1	0·75
(*b*) Low Level .	0·325	0·041	7·9 : 1	0·56
Whitehill No. 4 .	1·35	0·059	22·8 : 1	2·34

The following observations can be made relating to Table I:—

(1) In regard to both organic matter and content and C/N ratio, the Wittebergen soil stands clearly apart from the other three soils.

* This soil has a high iron content.

(2) Whitehill Nos. 1, 2, and 3 have a very low organic matter content.
(3) The C/N ratios of Whitehill Nos. 1, 2, and 3 are of the 10-12 : 1 order; Nos. 2 and 3 being less than 10 : 1.
(4) The C/N ratio of Whitehill No. 4 is 22·8 : 1—the order of C/N ratio found in virgin soils of the winter rainfall region of Cape Province. (Isaac, 1935.)
(5) Whitehill No. 3 shows a decreasing organic matter content and C/N ratio with increasing depth. This result agrees with that previously obtained for soils of the winter rainfall area. (Isaac, 1935.)

Karroo Poort.—Soil collected in a very barren and stony area of Karroo beyond Karroo Poort.

Soil over Dwyka Shales.

p_H	7·3.
Nitrogen	0·065 per cent.
Carbon	0·32 ,,
Organic Matter	0·55 ,,
C/N ratio	5 : 1.

This soil contains 0·454 per cent. chlorine; assuming the chlorine to be present as sodium chloride (NaCl), the soil would contain 0·749 per cent. of this salt.

Ouberg Pass.—Soil very stony and covered for the most part by succulents.

Soil over Witteberg quartzite.

p_H	7·6.
Nitrogen	0·081 per cent.
Carbon	0·876 ,,
Organic Matter	1·51 ,,
C/N ratio	10·85 : 1.

A Comparison of the Organic Matter of the Soils investigated, estimated on a basis of Carbon and of Nitrogen.

The use of the formula $N \times 20$ for the estimation of organic matter content was found to be unsuitable for the soils of the winter rainfall area (Isaac, 1935), and Table II. indicates that it is equally unsuitable for those of the semi-arid region. Whitehill No. 4 is not included in the table as it is essentially a winter rainfall soil. Nitrogen factors other than 20 have been used, and in the case of the soils under consideration $N \times 16$ gives a somewhat better series of results, but this factor is also unsuitable. It is clear that the estimation of soil organic matter on a basis of nitrogen is unsatisfactory.

TABLE II.

Soil.	C × 1·724 per cent.	N_2 × 20 per cent.	N_2 × 16 per cent.
Whitehill No. 1 .	1·19	1·02	0·82
Whitehill No. 2 .	0·703	0·84	0·67
Whitehill No. 3—			
(*a*) High Level .	0·75	1·04	0·83
(*b*) Low Level .	0·56	0·82	0·66
Karroo Poort .	0·55	1·30	1·04
Ouberg Pass .	1·51	1·62	1·30

The Karroo Poort soil is particularly instructive. The organic matter content (C × 1·724) is only 0·55 per cent. This soil is not only stony and practically devoid of a vegetative cover but contains 0·454 per cent. chlorine, which, calculated as sodium chloride, gives a value of 0·749 per cent. McLean (1930) gives figures for a saline Californian soil of C/N ratio 2·0 : 1, which may be compared to the Karroo Poort soil of C/N ratio 5 : 1. He comments on the impossibility of estimating the significance of this result without further study. Unfortunately no figures are given for carbon, so that it is not possible to calculate the organic matter content for comparison.

DISCUSSION.

An examination of the C/N ratios of the six soils investigated reveals an average value of 11·7 : 1, or, omitting Whitehill No. 4 and Karroo Poort, the ratio is reduced to 10·6 : 1. The soils of the winter rainfall area of the South-West Cape have been shown to have an average ratio of 15 : 1 (Isaac, 1935). It thus seems evident that the C/N ratio of soil organic matter tends to be smaller under semi-arid conditions. The exceptional case—Whitehill No. 4—lends confirmation to this view. Whitehill No. 4 represents a sample taken on the north facing side of the Wittebergen, the available moisture being consequently higher (p. 250)—conditions approximating to those of the winter rainfall area obtaining in this case. With regard to previous work on the variation of C/N ratio with climatic conditions, although the available evidence is insufficient to draw definite conclusions, Sievers and Holz (1923 and 1926) have found a slightly smaller ratio for the more arid soils investigated.

The average percentage of organic matter in the soils here investigated is decidedly lower than that of the winter rainfall soil series which gave an average of 2·6 per cent. for ten cultivated soils, whereas for the present

series the average is 1·17 per cent. for six soils, or, excluding Whitehill No. 4, 0·96 per cent. There is thus approximately three times as much organic matter in the soils from the more humid region. The figures are given in Table III.

TABLE III.

Soil.	Organic Matter, per cent. C × 1·724.	C:N ratio.
Karroo Poort	0·55	5·0 : 1
Whitehill No. 3—		
(*a*) Low Level	0·56	7·9 : 1
(*b*) High Level	0·75	8·3 : 1
Whitehill No. 2	0·703	9·7 : 1
Whitehill No. 1	1·19	13·5 : 1
Whitehill No. 4	2·34	22·8 : 1
Ouberg Pass	1·51	10·9 : 1

The high organic matter of Whitehill No. 4, as compared with the others, is further justification for considering it as being of the winter rainfall type. On the other hand, the Karroo Poort soil is exceptional in having a high chloride content. It is instructive to note that although the organic matter content is the lowest, the figure for nitrogen is slightly above the average value for the others.

On the other hand, the average nitrogen content of the five semi-arid soils, 0·058 per cent., is slightly more than half that of the soils of the winter rainfall area, 0·103 per cent. This confirms the findings of Sievers and Holz (1923) to the effect that the organic matter of arid soils contains more nitrogen than that of humid soils. They quote Hilgard's view that the smallness of many humus percentages in the arid regions does not necessarily mean a deficiency in the supply of nitrogen (Hilgard, 1912). Hall, discussing the nature of humus, states that "during the formation and continued decomposition of humus, the carbohydrates appear to be first attacked and the nitrogen bodies, *e.g.* the nucleins in particular, resist the action of bacteria. For this reason, where we find the proportion of humus in a soil is low, the proportion of nitrogen in the humus itself will be high (since) the decay of humus falls more heavily on the purely carbonaceous part of the material" (Hall, 1921). In support, the results obtained by Juritz (1914) on the soils of the Oliphants River valley irrigation scheme may be quoted. He found an average nitrogen content of 0·04 per cent. for thirty semi-arid soils.

The relative increase of nitrogen in the organic matter discussed above is an instance of the general theorem which has been shown to hold for the winter rainfall series—that the C/N ratio tends to narrow with a decreasing organic matter content in the soil (Isaac, 1935). Arranging the Whitehill soils in increasing order of C/N ratios (Table III), we see the corresponding increase of organic matter content. It is well to bear in mind in making comparisons, that the soils treated in this paper are virgin, and that such soils show both higher organic matter contents and wider C/N ratios than cultivated soils. The open vegetation and abundance of stones would, however, tend to reduce this difference.

The soils here dealt with are different from those of the winter rainfall area in their hydrogen-ion concentration, which influences the activities of the micro-organisms. These soils are neutral to slightly alkaline, whereas the series previously investigated are acid. This is a further reason for regarding Whitehill No. 4, with a p_H of 6·4, as belonging to the winter rainfall series.

Summary.

1. The semi-arid soils investigated are shallow and stony and, excepting Whitehill No. 4, are neutral to slightly alkaline in reaction. Whitehill No. 4 has a p_H of 6·4.

2. Carbon was determined by the sulphur dioxide reduction method of Robinson, total nitrogen by a modification of the method of Scales and Harrison, and organic matter by the formula $C \times 1{\cdot}724$. The unsuitability of the nitrogen values as a basis for the estimation of soil organic matter is demonstrated.

3. The average C/N ratio of the semi-arid soils, but omitting Karroo Poort, is 10·6 : 1. This value, as contrasted with that previously obtained for the winter rainfall area soils (15 : 1), affords a striking instance of climatic effect on the C/N ratio of soil organic matter. The value of this contrast is further enhanced if we bear in mind the fact that the figure for the winter rainfall series refers to cultivated soils, whilst the semi-arid soils dealt with are virgin.

4. Karroo Poort soil has the remarkably low C/N ratio of 5 : 1. This soil is saline.

5. In the case of Whitehill No. 3, where soil samples were taken at two different depths, there was a decrease in the C/N ratio and in the organic matter content with increasing depth.

6. Whitehill No. 4 is essentially a soil of the winter rainfall area type, with an organic matter content of 2·43 per cent. and a C/N ratio of 22·8 : 1.

7. The average organic matter content of the five semi-arid soils is 0·96 per cent., while the ten cultivated soils of the winter rainfall series

previously investigated yield an average organic matter content of 2·6 per cent.—a difference of nearly 3 : 1 in favour of the latter.

8. The average nitrogen content of the five semi-arid soils is 0·058 per cent., and that of the winter rainfall area soils 0·103 per cent. The value of the latter is somewhat less than twice that of the former.

9. A decreasing organic matter content is accompanied by a decreasing C/N ratio. This is particularly well seen in the Whitehill series.

We wish to thank Prof. R. H. Compton who made the necessary arrangements for the collection of selected soils at Whitehill. For the original of fig. 1 we are indebted to Miss F. M. Leighton. Lastly, we have pleasure in thanking Professor R. S. Adamson for his criticism of the manuscript of this paper.

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May 1935.

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SOME BIOLOGICAL NOTES ON *BOSCIA REHMANNIANA*, PEST., AND *OLEA VERRUCOSA*, LINK.

By Ernest E. Galpin, D.Sc., F.L.S., and E. A. Galpin.

(With Plates X and XI.)

(Read May 15, 1935.)

The strange-looking *Boscia rehmanniana*, locally known as Wonderboom or Mophipi, appears to be a survival in the central portion of the Transvaal from the period when desert conditions prevailed there, variously estimated by geologists at from 800 to 1000 years ago, and to be one of the oldest living representatives of that period.

It is always an interesting and fascinating study to attempt to reconstruct the former climatic conditions of a country, and most evidence hitherto collected has been of a geological nature. On this portion of the Transvaal, contrary to popular belief, geological evidence, mainly of aeolian action on the sandstones, the piling up of sand-hills, the wind erosion of sandstone koppies, and the formation of typical Kalahari pans, such as the Elephants Pan on Roodepoort, point to former arid conditions of quite recent date. A study of two trees lends botanical support to this evidence.

Boscia rehmanniana grows abundantly in the brak soil of the Thomboti (*Spirostachys africana*) association and occasionally in the red basaltic loam of the Acacia veld, particularly on the farms Zyferkraal, Du Toit's Kraal, and Roodepoort in the neighbourhood of Naboomspruit. It is also found, sparsely, growing in the belt of secondary limestone in the Zebediela Location.

The absence of young trees and seedlings appears to foreshadow its eventual extinction in the above areas.

The existing trees are all very old. They bear flowers and seeds every year in great abundance, thousands on each tree, but during a residence of sixteen years in their midst we were never able to find any young seedling plants, in spite of searches made from time to time, until a couple of years ago, after some years of the lowest rainfall recorded in this area, two seedling plants made their appearance in between some rows of seventy

feet high eucalyptus, where the ground is very dry by reason of the roots of the latter absorbing the soil moisture.

We have proved that the absence of young plants is not due to infertility of the seeds. Germination tests made by E. A. Galpin at Mosdene have shown fifty per cent. of the seeds to be viable, and healthy young plants have been grown from them. Neither do we think it due to the destruction of the seeds by birds, insects, or other pests. *Euclea lanceolata*, which grows everywhere in close association with *Boscia rehmanniana*, bears fruit equally attractive to such pests, yet produces many seedling plants and is increasing in abundance.

In August 1934 we paid a visit to the neighbourhood of the Zoutpan on the northern side of the Zoutpansberg, at its western extremity, where Mr. van der Goot, the resident joint-owner of the Saltpan, informed us that the rainfall is eight inches per annum as contrasted with twenty-five inches, which until the recent abnormally dry years has been the average rainfall on the Roodepoort portion of the Mosdene estate.

Here at Zoutpan, with only one-third of the rainfall, we found *Boscia rehmanniana* abundant, growing much more luxuriantly than in the central Transvaal area and surrounded by numbers of healthy seedling plants. A comparison of the accompanying photographs affords striking illustration of the much greater luxuriance of the trees growing under eight inches of rainfall.

The conclusion is that the moister conditions now prevailing in the central Transvaal area are not congenial and that with the passing away of the existing old trees the species will die out in this area.

Old as these trees undoubtedly are, they still have great vitality and have a method all their own and not observed in any other plant of renewing their youth.

Their larger branches, usually two or three spreading at equal distances around the trunk, are gradually borne down by the great weight of the besom-like tangle of their numerous, rigid, intricate branchlets and, instead of breaking at their junction with the trunk, pull away a piece of the latter as thick as themselves and thus relieve the strain. A new and younger growth of bark spreads over the portion of the trunk torn out and continues to do so as further portions are exposed by the gradual dropping and pulling away of the branches till frequently the trunk is split right down to its base.

The central portion of the tree, not appropriated by its main branches in this way, gradually decays, leaving a much younger-looking two or three stemmed tree, which now having much new bark on its stems has a greatly prolonged life to carry it on to the next stage in its life-cycle.

On sawing through the trunk of a mature tree there will be found two or three roughly concentric rings of thick bark-like substance. This gives

a line of least resistance, and the splitting of the bole takes place along the plane of these rings which appear to assist in the bark regrowth and the regeneration of the tree. The bark regrowth over the fissuring is at first of a net-like character, and the exposed wood in the bole dies and withers and is for the most part either eaten by termites or rots and falls away. That portion of the wood pulled away with the branches in the course of years is gradually, though frequently never entirely, covered by bark, thereby contributing to the gnarled appearance of the tree.

The reinforced, outwardly leaning branches continue to drop until at a certain stage, before their tips touch the ground, the terminal portions which have fallen below the horizontal die back to the thicker horizontal portions. From each of these one or more strong-growing, erect, adventitious shoots are put forth.

By a continuation of the process of tearing down the bole the main branches are gradually lowered to a horizontal position until they eventually reach the ground, by which time the adventitious shoots have already attained the shape of mature trees, but vary in size from a small seedling-like tree to one with a bole of six inches or more in diameter. The horizontal portions become covered with soil and slowly rot away. A vigorous shoot also occasionally grows from the underground portion of the main stem.

On scraping away the ground near any of the younger-looking trees you will invariably find in the centre of the group, or, if there be only one tree or a single row of trees, at the distance of their fallen, horizontal trunk, the remains of the original stem and frequently also the buried remains of the horizontal trunks from which they sprouted.

Olea verrucosa, Link.

Additional evidence of a comparatively recent change in the climate of this portion of the Transvaal is seen in the immense number of stumps of large size of *Olea verrucosa* on Roodepoort, mostly weathered down to nearly ground level, some to beneath the surface, whilst, in a few cases, the remains are still standing of hoary, much honeycombed, old trunks. An accompanying photograph shows one of the latter which a dozen years ago had a few, straggling, miserable, green branchlets.

From these old stumps, dotted over the veld at an average distance of fifty yards apart, *Olea verrucosa* undoubtedly must at one time have been the dominant tree over a considerable portion of Roodepoort and have been as abundant there as *Spirostachys africana* now is in the Thomboti association on the adjoining farm Zyferkraal.

At present these old *O. verrucosa* stumps form the centre of small two or three feet high earth mounds overgrown with bushes. These trees evidently

acted as pioneers in the formation of the bush clumps which are now so conspicuous a feature on a large portion of Roodepoort.

Growing out of the earth mounds referred to, one occasionally still finds a tree of *Olea verrucosa*, of comparatively poor growth, adjacent to an old stump, but there are probably not more than fifty such trees on the whole of Roodepoort, 1825 morgen in extent.

Boscia rehmanniana, Pest. At Zoutpan, Zoutpansberg.

Boscia rehmanniana, Pest. On farm Zyferkraal, Naboomspruit. Showing bent-down branches with adventitious shoots. Central trunk rotted away.

Photos by E. A. Galpin. *Neill & Co., Ltd.*

Boscia rehmanniana, Pest. On farm Zyferkraal, Naboomspruit. Regrowth from prostrate branches.

Olea verrucosa, Link. Remains of ancient tree on farm Roodepoort, Naboomspruit, which up to a few years ago still had a few living twigs.

Photos by E. A. Galpin. *Neill & Co., Ltd.*

ON THE FLORA OF A HIGH MOUNTAIN IN SOUTH-WEST AFRICA.

By John V. L. Rennie, M.A., Ph.D.
(Rhodes University College, Grahamstown, South Africa.)

(With Plate XII.)

(Read May 15, 1935.)

It is generally accepted that the rich and peculiar flora of the southern and south-western districts of the Cape Province is an ancient one that was formerly more widespread on the African continent. The occurrence of characteristic elements of this flora at high altitudes on the mountains of tropical Africa can scarcely admit of any other interpretation. Changing climatic conditions and the advance of the African flora have led to the isolation of the old temperate type on these mountains as a series of relics. It is probable that this ancient flora had its origin in the south and that northward migration took place at some former epoch when climatic conditions were favourable to the spread of temperate species. The extension of several Cape genera into the coastal districts of Pondoland and Natal, and along the Drakensbergen and the mountains of the Rhodesian border into East Africa, has frequently led to the assumption that migration was essentially, if not entirely, along an eastern route.

The writer is indebted to Mrs. M. R. Levyns, D.Sc., for drawing his attention to a lengthy discussion on the distribution problem published by H. Weimarck in his recent "Monograph of the Genus *Cliffortia*" (Lund, 1934, 229 pp.). Commenting on the occurrence of *Cliffortia* and *Sparmannia* in Angola, Weimarck states (p. 219) that "Just as the migratory route of *Sparmannia* must in all probabliity have run from Nyassaland to Angola so *Cliffortia angolensis* has no doubt come from the east. For the group of species to which this type belongs attains a high degree of differentiation from the Cape north-eastwards to the Drakensbergs and from there to the mountains of tropical East Africa. Generally speaking, all facts indicate that the elements of the Cape flora migrated along this route to the north and to Angola. If this is not the case then we might expect to find relic Cape plants in South-West Africa, where the Brandberg reaches an altitude of 8277 feet and . . . the Auas Range 7886 feet. The rainfall

must be considered sufficient to enable Cape species to hold on there, for even at Tsumeb at an altitude of only 4230 feet the rainfall . . . amounts to 22·06 inches."

It seems opportune to place on record the occurrence of certain species in the Auas Mountains which can be interpreted as relics of the Cape flora, and which indicate that migration of at least certain elements of that flora took place through South-West Africa. The material was collected and identified by the writer in 1925 and has been critically re-examined by Mrs. Levyns, and is preserved in the herbarium of the Botany Department of the University of Cape Town.

The Auas Mountains are crossed by the main railway line to the Union just south of Windhoek and form the most elevated part of the Damaraland highlands and the main watershed of South-West Africa. The range extends in an E.N.E.–W.S.W. direction for over thirty miles and has a mean altitude of well over 6500 feet. East of the railway the range is in the form of a prominent and relatively narrow escarpment, rising to about 2500 feet above the surrounding country and made up essentially of quartzites of pre-Cambrian age. To the west the range broadens out considerably into an extensive mountainous plateau. The highest point of the range, the Moltke Blick, is about nine miles south-east of Windhoek and lies to the east of the railway, and attains an altitude of 8148 feet. The species referred to below were collected during a brief visit to the Moltke Blick and the summit of the escarpment in the vicinity of that peak.

There are no available rainfall records for the Auas Mountains. The average fall at Windhoek, 5320 feet above sea-level and only nine miles distant, from readings taken over a long period of years, is in the neighbourhood of 15 inches per annum, practically all of which falls during a limited period in the summer months. The annual rainfall is, however, very variable, the average for the five years 1928–9 to 1932–3 amounting only to 6·53 inches, and in two successive years in that period the fall was under 4·5 inches.* There is no reason to believe that the rainfall on the summit of the Auas Range is very much in excess of the fall in Windhoek, though condensation on exposed surfaces at the higher altitude must increase the total precipitation by a certain amount.

The thornveld, characteristic of the highlands of central Damaraland, persists to a considerable altitude in the Auas Mountains: but the trees gradually thin out upwards and become reduced in height, and in the eastern part of the Auas only occasional very stunted specimens of *Acacia* are met with in sheltered positions in the highest portions of the range. At and near the summit trees are replaced by several species of small shrubby plants, mostly small-leaved and up to two or three feet in height,

* Figures from Official Year Book, Union of S. Africa, 1932–3, p. 987.

the vegetation being essentially mountain grassland with scattered shrubs. The latter belong to species which have a restricted vertical range of a few hundred feet. The most abundant species is *Stoebe plumosa* Thunb., and others of common occurrence are *Osyris abyssinica* Hochst., *Euclea*? sp., *Walafrida* sp., *Eriocephalus aspalathoides* DC., *Iphiona polygalifolia* Benth. and Hook., and *Senecio cinerascens* Ait. A number of plants of *Passerina* cf. *glomerata* Thunb. were found growing in the immediate neighbourhood of the beacon which marks the highest point of the Moltke Blick, and the species was not noticed elsewhere. A few plants of a species of *Melianthus* with scarlet flowers were also seen. In rocky situations there is a notable increase in the number of succulents, particularly small species belonging to the family Crassulaceae.

Stoebe plumosa has its centre of distribution in the south-western districts of the Cape Province, and the writer is informed by Mrs. Levyns, who is at present investigating the genus and has examined all the material at Kew, the British Museum and in South African herbaria, that previous records range from East London to the Giftberg south of Van Rhyns Dorp. Similar plants from the eastern side of the Union belong to an allied species. Dinter's *Elytropappus ruschianus*, collected at 2200 m. at Lichtenstein in the western part of the Auas, has been found to be *Stoebe plumosa*, so the species apparently has a wide distribution in these mountains. There are no other records of the genus from South-West Africa.

Osyris abyssinica is a very frequent shrub of the mountain ranges of the southern part of the Cape Province from Cape Town to Grahamstown, and is widespread through the eastern part of the Union, extending northwards through East Africa to Arabia. Records from the drier western side of the subcontinent are rare, apparently including only the Huilla Plateau, and in South-West Africa Windhoek and the Otavi Mountains.

The *Euclea*? was unfortunately not collected, but *E. lanceolata* E. Mey. and *E. undulata* Thunb. have been recorded from near Windhoek. These well-known South African species are known from a number of isolated localities in South-West Africa, *e.g.* Aus and the Otavi Mountains, and the former is known also from the Huilla Plateau in Angola. Other species of the genus, *E. pseudebenus* E. Mey. and *E. multiflora* Hiern, have a similar northward distribution.

The *Walafrida* has not been identified. The genus is almost confined to South Africa, and the only existing record from South-West Africa appears to be *W. nachtigali* Rolfe from near Gobabis, a different species.

Iphiona polygalifolia, included in *Pegolettia* in Flora Capensis, is wide ranged in the Cape Province, but in South-West Africa has only been recorded from near Windhoek and also near Aus in Great Namaqualand.

Senecio cinerascens has been collected at 1500 m. at Aus by Dinter,

but other records are confined to the western part of the Cape Province, where the species is met with from the Zwart Ruggens north of Ceres to the Kamiesberg.

The genus *Passerina* ranges from Little Namaqualand through the mountains of the southern part of the Cape Province to the Natal coast and the Drakensbergen, but has its centre of distribution in the south-western districts. The specimens from Moltke Blick were sent for determination to Professor D. Thoday, who has recently revised the genus and studied its distribution (Ann. Bot., xxxix, pp. 175–208, 1925). The material was not in flower, having been collected in mid-winter, but on vegetative characters Professor Thoday thinks that it belongs to *P. glomerata*, a species with a fairly wide range in the mountains of the western districts of the Cape, from Tulbagh to the Olifants River, and after a gap of 100 miles in the Kamiesberg of Little Namaqualand. The occurrence of the genus near Windhoek, over 500 miles north of the Kamiesberg, finds a curious parallel in the east, where *P. montana* is found near Umtali, 400 miles north of its occurrence in the Drakensbergen. The genus has not previously been recorded from South-West Africa.

The *Melianthus* was not collected, but all the described species of the genus are essentially South African. *M. comosus* Vahl. has, however, been recorded from several localities in South-West Africa, including Aus, the Great Karasberg, Lichtenstein in the Auas Mountains, the Omatako and the Waterberg.

The Auas Mountains are within the Tropics in lat. S. 22° 40′ and are very nearly half-way between the northernmost outlier of the Cape Flora on the Kamiesberg of Little Namaqualand (lat. S. 30° 15′) and the Huilla Plateau east of Mossamedes in Angola (lat. S. 15°) where *Euclea*, *Cliffortia* and other Cape genera make their appearance, being about 500 miles from each. The isolation of the *Stoebe* and the *Passerina* is particularly striking, the nearest existing records of the genera being from the western Cape; the northernmost previous record of *S. plumosa* is the Giftberg (lat. S. 31° 50′), as much as 600 miles south of the Auas Mountains.

It is possible that further exploration of the Auas and of other high mountains of South-West Africa will bring to light additional species belonging to typically Cape genera, but the list of such species will probably not be greatly extended. The numerous broken ranges and isolated peaks that rise from the Great Plateau in that territory rarely exceed 7000 feet in altitude, and some of them, like the Great Karasberg (7218 feet) and the Brandberg (8550 feet), the latter the highest point in South-West Africa, are situated in districts of considerable aridity. Pearson (1914, Ann. Bolus Herb., i, p. 8) has reported that in the Great Karasberg, "Even at the highest elevations there is no well-marked trace of the old Cape flora which

is so prominent at similar elevations on the Kamiesberg and the Huilla Plateau," and the accompanying list includes only such Cape species as are widespread in the drier parts of the Cape Province, *e.g. Melianthus comosus* Vahl. and *Montinia caryophyllacea* Thunb. The annual rainfall varies considerably throughout the territory, and even in the north-eastern districts where the mean annual rainfall approaches 25 inches, the fall in some years hardly exceeds 10 inches. The Auas mountains, by reason of their considerable areal extent, high mean altitude and moderate rainfall, probably form the most favourable area in South-West Africa for the preservation of relics of the Cape flora, but their existence there must be somewhat precarious. The Otavi Mountains (7000 feet), south of Tsumeb, and the Gansberg (7649 feet) and other peaks west of Rehoboth might also repay a careful search.

The writer wishes to express his appreciation of the assistance given by Mrs. M. R. Levyns, who not only identified the species here referred to, but went to much trouble in consulting the records of the genera concerned in the Bolus Herbarium and the unpublished list of South-West African plants compiled by Miss S. Garabedian of the South African Museum.

FIG. 1.—Summit of the Auas Mountains near the Moltke Blick, showing slopes on southern side. Shrubs in foreground chiefly *Stoebe plumosa*.

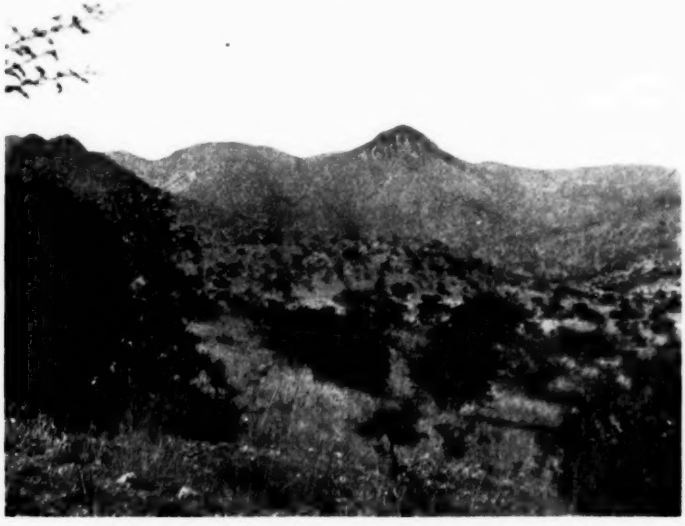

FIG. 2.—General view of the Auas Mountains a little to the west of the Moltke Blick, seen from the north, showing thornveld. The nearer prominent peaks are necks of trachyte.

THE "GALJOEN" FISHES OF SOUTH AFRICA.

By J. L. B. Smith.

(With Plates XIII–XVII.)

(Read May 15, 1935.)

Family DICHISTIIDAE nov.

Body compressed, ovate or elevated. Mouth terminal, slightly protractile. Maxilla expanded distally, with large supero-median expansion (Pl. XVII, F); extremity not entirely covered by preorbital. No supramaxilla. Premaxillary pedicels moderate (Pl. XVII, G), not reaching frontals. A small pointed supero-median expansion on each premaxillary ramus, sliding behind maxilla. A single series of elongated compressed incisiform teeth in each jaw, with similar, but very much smaller teeth behind (Pl. XVII, C and G). Palate and tongue edentate.

Gill-membranes united forming a moderate fold across the throat, narrowly fused below with isthmus.

Two nostrils, close together.

Air bladder not constricted, nor posteriorly bifurcated.

Parietal crests very low: nó transverse ridge at posterior margin of frontals. Supra-occipital fairly elevated, anterior edge thickened. A strong subocular shelf.

Vertebrae 25(10 + 15): precaudals with parapophyses from the fourth. Ribs, inserted behind and above level of parapophyses, sessile except last three.

Spinous dorsal of stout spines, shorter than soft fin. Anterior to the spinous dorsal several overlapping antrorse recumbent spines below the skin, the anterior (inferior) resting on the apex of the supraoccipital, the posterior ankylosed with the basipterygials of the first two exposed spines. Soft fins densely scaly, scaling not to margin.

Scales ctenoid, strongly adherent, deeply embedded.

The various taxonomic positions hitherto assigned to the genus *Dichistius* Gill would appear to have been selected in more or less arbitrary fashion. Regan (Ann. Mag. Nat. Hist., 1913 (8), vol. xii, p. 127) stated that it "probably pertained" to the **Girellidae,** in which family it was later placed by Barnard (Ann. S.A. Mus., 1927, vol. xxi, p. 635). Fowler (Proc. Ac. Nat. Sci. Phil., 1925, vol. lxxvii, p. 233) at first considered *Dichistius* to fall in the **Sparidae;** later (Bull. U.S. Nat. Mus., 1933, vol. xii, p. 216) in the **Kyphosidae,** while more recently (Proc. Ac. Nat. Sci. Phil., 1934, vol. lxxxvi, p. 476) for one of the species he has proposed a new genus placed in the **Scorpididae.**

A critical examination of the genus *Dichistius* has shown that there is

little to choose between these various diagnoses, since this genus appears to differ in about equal degree from the general diagnosis of each of those four families, showing perhaps least affinity with the **Girellidae.** It would, however, appear to differ from any one of the families **Kyphosidae, Sparidae** and **Scorpididae** by characters at least as significant as those which are generally accepted as justifying the separate existence of those three families.

The dentition, the exposed maxilla, and the nature of the vertebral column and appendiculars, among other features, would appear to rule out its inclusion in the **Girellidae.** The strong subocular shelf, and the nature of the vertebral column are not Kyphosid, while these features, together with the united gill-membranes, would scarcely allow of its inclusion in the **Scorpididae.** It is also well differentiated from the **Sparidae** by the relations of the maxillary bones alone.

Dichistius would actually appear to have closest affinity with the **Scorpididae.** In some respects, however, it would appear to be a connecting link between that family and the **Kyphosidae,** *e.g.* according to Regan (*loc. cit.*, p. 126) the **Scorpididae** all have 25(10 + 15) vertebrae, with parapophyses from the 3rd or 5th precaudals: the **Kyphosidae** (Regan, *loc. cit.*) have 24(10 + 14), with parapophyses from the 4th. *Dichistius* has 25 vertebrae, with parapophyses from the 4th. The dentition also is intermediate between that of the **Kyphosidae** and that of the **Scorpididae,** approximating, however, more closely to that of the former family.

From the skeletal and structural evidence I have obtained, it would appear as reasonable to unite the families **Scorpididae** and **Kyphosidae** as to place *Dichistius* in either. It is now proposed to regard *Dichistius* as the type of a separate family. It is frankly admitted that this diagnosis can at best be provisional only, since I have at my disposal only one genus, *Kyphosus* Lac. of the KYPHOSIDAE, and only *Neoscorpis* J. L. B. Smith of the **Scorpididae.** For further information in regard to skeletal features in those families I have relied upon Regan (*loc. cit.*). It may here be indicated that *Neoscorpis* differs from Regan's diagnosis (*loc. cit.*, p. 126) of the **Scorpididae** in that there is no subocular shelf. (I have examined a head of *Parascorpis* Blkr., and a strong subocular shelf is present.) Further, the hydrostatic organ is posteriorly bifurcated into two caudal extensions after the fashion of that of *Kyphosus* (that of *Parascorpis* does not, *fide* Dr. Barnard, *in litt.*). Nevertheless *Neoscorpis* agrees in the main with Regan's diagnosis of the **Scorpididae,** in which it undoubtedly falls.

It may be indicated that the nature of the obsolescent portion of the dorsal fin in Perciform fishes is a feature which has apparently not been assigned its true taxonomic significance, and which may assist in elucidating hitherto obscure relationships.

In *Kyphosus* there are 11 exposed dorsal spines. Anterior to and quite separate from these, below the skin, is the rudiment of a single-spined, probably separate, dorsal, the spine being so far obsolete that it cannot be determined whether it was originally antrorse or retrorse. In *Neoscorpis* there is evidence of the existence at some period of two separate spinous dorsals, of which the first was composed of three spines, the anterior of which was antrorse and procumbent, the middle spine either antrorse or retrorse, while the posterior spine was likely normal and retrorsely depressible. The posterior spinous dorsal of *Neoscorpis* is also evidently undergoing reduction. That fin would appear at some stage to have consisted of 10 exposed spines, proportioned much as the 10-spined fin of *Dichistius*. From 2 to 4 of the anterior spines have already become obsolete, and reduced to subcutaneous dilations of the basipterygial apices. In some specimens the anterior exposed spine is so minute that its presence may be ascertained only upon dissection.

In *Dichistius*, immediately anterior and adjacent to the exposed 10-spined dorsal, is a subcutaneous structure of four overlapping antrorse procumbent spines, of which the posterior (and superior) is fused with the united basipterygials of the first two external spines (Pl. XVII, B), while the anterior rests upon and over the supraoccipital apex. It may be noted that an exactly similar structure is present in *Platax* Cuv., *Drepane* Cuv., and *Tripterodon* Plyfr. *Dichistius* is related to this group of allied genera in other ways, and in some respects falls intermediate between these genera and the natural group of the **Scorpididae, Kyphosidae** and **Sparidae.**

The species of the single genus of the **Dichistiidae** are confined to the southern African region, and are found only in shallow water.

Genus Dichistius Gill.

1888. Gill, Proc. U.S. Nat. Mus., vol. ii, p. 68. (Type *capensis* Cuv. *Dichistius* proposed to replace *Dipterodon* Cuv., preocc.)

1927. Barnard, *loc. cit.*, p. 635. (*Dipterodon* Cuv.)

1933. Fowler, Bull. U.S.N. Mus., vol. xii, p. 215. (*Coracinus* Gron.)

1934. Fowler, Proc. Ac. Nat. Sci. Phil., 1934, vol. lxxxvi, p. 476. (*Drepanoscorpis.*)

Body compressed, elevated or ovate. Mouth terminal, slightly oblique, protractile. Maxilla not completely covered by preorbital. Posterior teeth in each jaw incisiform, very small, in two rows, inserted on roof and floor of mouth well behind the exterior incisors. Pharyngeal teeth enlarged, obtuse, molariform (Pl. XVII, D and E).

Gill-rakers moderate in size and number. Branchiostegals 7, basal membrane scaly. Gill-membranes scaly, united, forming a fold across the throat, narrowly united with isthmus.

Two nostrils, close together, the anterior much the larger, each with a plain flap. Preorbital of moderate and uniform depth, lower margin entire, posterior portion scaly. Preopercle margin serrate (Pl. XVII, A).

Dorsal with deep scaly sheath, of 10 stout spines, the middle the highest, deeply

notched between spinous and soft portions. Soft dorsal longer than spinous, anterior rays forming a prominent lobe, sometimes sub-falcate. Soft fin densely scaly for at least the basal half. Anal of three spines, first short and stout, remaining two subequal in length. Soft anal of 13 to 14 rays, the anterior elevated forming a lobe. Scaly as for dorsal. Ventrals inserted well behind pectorals, of moderate size, slightly shorter than pectorals. Caudal slightly forked. All fins scaly.

Scales firmly adherent, small, ctenoid, lateral line tubular scales much smaller than adjacent scales.

The original generic name was *Coracinus* Gron. [*cauda lunata* Gron., 1763].

According to Mr. Norman of the British Museum, by Opinion 89 of the International Commission, Gronovius is ruled out, unless his name can be shown to have been adopted by some later accepted binomial author. There appears to be no record of any such usage between 1763 and 1888, when Gill (*loc. cit.*) proposed *Dichistius*. In view of the generally accepted Rules and Opinions of the International Commission, therefore, it appears that *Dichistius* Gill must replace *Coracinus* and *Dipterodon*.

Fowler's *Drepanoscorpis* (*loc. cit.*) is somewhat difficult to understand. His description of the species *Drepanoscorpis gilchristi* agrees in all particulars with his own earlier descriptions of *Dipterodon capensis* C. and V., and of *Coracinus capensis* C. and V. It is possible that Fowler recognised *gilchristi* as being identical with those specimens earlier described as *capensis*, but he makes no mention of this. There is no room for doubt that *gilchristi* Fowler is identical with the species *multifasciatus* Pell. (see below). Since that species and *capensis* are emphatically congeneric, Fowler's genus falls into the synonymy of *Dichistius*.

The original species of this genus must have been one of the earliest typical Cape fishes to be recognised by the early settlers, as it is fairly abundant in shallow water. Only one species was recognised until Pellegrin (Bull. Soc. Zool. Fran., 1914, vol. xxxix, p. 231) described *multifasciatus* (type locality Madagascar) and distinguished it from the common Cape *capensis* C. and V. This diagnosis has not been accepted by subsequent workers, partly because Pellegrin laid stress upon certain features which can hardly ever be of much taxonomic significance. Nevertheless as is shown below, *multifasciatus* is a perfectly valid species, being clearly differentiated from *capensis* by numerous features.

Examination of material from all parts of the South African coast has revealed that a third species, *falcatus* n. sp., is also present. This may immediately be distinguished from the other two species by its general outline, but it has proved exceedingly difficult to reduce the differentiation to an immediately appreciable quantitative form. This species is exceedingly close to *capensis*, and may even be regarded as merely a sub-species.

Since trinomialism does not yet appear to be generally accepted ichthyological practice, *falcatus* is here described as a distinct species.

The following table indicates some of the features in which differentiation between the three species is found.

	capensis.	*falcatus.*	*multifasciatus.*
Depth peduncle in body depth . .	3·1–3·2	3·0–3·2	3·9–4·1
Pectorals in body length . . .	4·0–4·1	3·6–3·8	3·5–3·8
Ventrals in body length . . .	4·5–5·0	4·0–4·5	3·7–4·0
Preorbital depth in head . . .	6·5–7·2	6·0–6·6	5·3–5·6
Base of soft dorsal with length of head	Less than.	Less than.	Greater than.
Lateral rows of scales . . .	75–78	73–78	83–86
Dorsal profile curve . . .	Broken at eye.	Smooth.	Smooth.
Anterior dorsal rays . . .	Not falcate.	Falcate.	Not falcate.

Besides these features, there are numerous others, which are indicated below in the descriptions. The distribution of the three species is of interest: *capensis* appears to occur from the Cape to about East London, *falcatus* n. sp. from about Knysna to Natal, and *multifasciatus* from about Algoa Bay to Madagascar.

Key to the Species.

I. Least depth of peduncle 3·0–3·2 in body depth.
  Body more than twice as long as deep. Cross bars, if present, of uniform width.
    A. Pectorals 4·0–4·1 in length of body. Anterior dorsal rays not falcate . . . . . *capensis.*
    B. Pectorals 3·6–3·8 in length of body. Anterior dorsal rays falcate . . . . . *falcatus.*

II. Least depth of peduncle 3·9–4·1 in depth of body.
  Body less than twice as long as deep. Cross bars alternately wide and narrow . . . . . *multifasciatus.*

The length of the pectoral is measured from the body to the tip of the fin when the latter is held at right angles from the side.

Dichistius capensis (C. and V.).

(Plate XIII.)

1831. Cuvier and Valenciennes, Hist. Nat. Poiss., vol. vii, p. 276, Pl. 188.
1908. Gilchrist and Thompson, Ann. S.A. Mus., vol. vi, p. 165. (*Dipterodon capensis* C. and V.)
1914. Gilchrist, Mar. Bio. Rep., vol. ii, p. 90. (*Dipterodon capensis.*)
1927. Barnard, Ann. S.A. Mus., vol. xxi, p. 635. (*Dipterodon capensis*, part), Pl. 25, fig. 2.

Body ovate, compressed but robust, maximum width 1·6–1·7 in head. Dorsal profile gently sloping to interorbital, steeper to snout tip. Snout distinctly blunt, almost vertical from prominent interorbital in some specimens.

Depth 2·2, length of head 3·2–3·3 in length of body. Eye 3·8 (Juv.)–4·5, snout 3·0–3·1, interorbital 2·5–2·6, postorbital part of head 1·7–1·8 in length of head. Preorbital uniformly deep, depth above end of maxilla 6·4–7·2 in head. The distance from the upper margin of the dorsal sheath at base of 4th dorsal spine to the nearest point of the lateral line distinctly less than post-orbital part of head.

Mouth moderate, terminal, slightly oblique, maxilla extends to below or almost below anterior border of orbit: in small specimens below anterior part of eye. Distance from hind margin of maxilla to upper margin of upper lip at snout tip 2·1 in postorbital part of head. Upper lip deep and fleshy, depth at snout apex 2 in eye. 20–26 compressed elongate incisiform teeth in upper jaw, 20–24 similar in lower jaw. Two rows of about 8 each of similar smaller teeth, concealed in fleshy pads, behind the outer series in each jaw. Palate and tongue edentate.

Gill-membranes united, forming a smooth fold across the throat, fused anteriorly below with isthmus. Gill-rakers moderate, 5–6 + 13–15, 1·8–2 in gill-filaments, which are 1·0–1·3 in eye.

D X, 18–19, inserted above midway between pectoral and ventral origins or slightly nearer the pectoral, deeply notched between spinous and soft portions. Spines fairly stout. First spine 10–14, 2nd 4–6, 3rd 2·5–3·3, 4th and 5th 2·2 in length of head, thereafter graduated shorter. Soft rays anteriorly elevated forming a blunted or pointed lobe, not falcate. Lobe extends beyond tip of tenth dorsal spine 1·7–2·1 in head, equal to or less than postorbital part of head. Base of soft dorsal shorter than head.

A III, 13–14, inserted below the origin of the soft dorsal. Spines stout, first 5·9–6·6, second 4–4·5, third 4·5–4·8 in length of head. Soft rays anteriorly elevated forming a broad lobe, which extends 1·9–2·2 in head beyond the apex of the third anal spine.

Pectorals 4·0–4·1 in length of body, tip reaches below more than an eye diameter short of the origin of the soft dorsal.

Ventrals 4·5–5·0 in length of body, tip does not reach origin of anal; in large specimens the tip does not reach beyond the vent.

Caudal moderately forked, peduncle 1·1–1·2 times as long as deep. Least depth of peduncle 3·1–3·2 in depth, 6·7–7·0 in length of body.

Scales ctenoid, larger on posterior part of body, all deeply embedded. Lateral line gently curved, tubular scales smaller than adjacent scales. Lateral rows 73–78, tubular scales 60–64; 28–30 above lateral line obliquely back from base of first dorsal spine. Whole body and head, except muzzle, scaly. Median fins scaly; on soft dorsal and anal scaling extends about half length of rays and is not very dense beyond the basal third. Bases of alternate dorsal spines scaly. Pectorals and ventrals scaly about three-fourths.

Colour.—Rather variable when taken from the water; either bright silvery, or with light or dark irregular blotches, or wholly dark. Uniform or with 7–9 uniformly wide cross bars, wider than the interspaces. Dorsal spines, dorsal and anal lobes, and ventral rays black or dusky. After death the colour is usually uniform dusky or almost black, with or without cross bars.

Locality.—Walfish Bay to Table Bay (Gilchrist); Cape Peninsula to Port Alfred, very occasionally entering tidal rivers, then rarely beyond the reach of the waves.

Length.—Up to 600 mm.

Eight specimens from 140 mm. up examined.

D. capensis is the well-known "Galjoen" (*Ang. Galleon*) of the Cape.

It is a somewhat polymorphous species, and sub-species will most likely eventually be proposed. It may immediately be distinguished from *multifasciatus* by the shallower body, by the heavier peduncle, and by the body markings, besides other features: from *falcatus* by the markedly shorter fins, as well as by the characteristic snub nose.

The colouration of the live fish is extremely variable, even in specimens from one restricted area. The live fish may be uniform, or blotchy, or mottled in various shades of silver to black. Cross bars are rarely observed on the live fish in the summer months, generally appearing, if at all, when the fish is moribund. The banded form is commoner eastwards from Knysna, and is more frequently observed during the winter months. When the fish is moribund the melanophores evidently expand fully, for whatever the colour of the live fish, soon after death it is almost black. It is possible that there is a nocturnal barred colour phase, such as I have observed in the species at present recognised as *Sparus sarba* Forsk, but as the "Galjoen" does not appear to feed during the night, information on this point is not available. Gilchrist (*loc. cit.*), who studied the colour phases of this species in an aquarium, is rather vague about the banded phase, and does not appear to have examined the specimens at night.

Gilchrist had in the aquarium noticed the great ease with which this species could turn and reverse its progress. These fishes must be extremely powerful, for they evidently swim freely even in turbulent surf. The general habits and environment of this species have frequently been outlined, and detailed repetition is unnecessary, but one or two characteristics call for special mention. From a rocky ledge overlooking moderately deep water at the edge of a reef, I have been able to attract several of this species by dropping into the water pieces of "Red-bait" (an Ascidian: *Pyura stolonifera*). These the fishes would seize right in the surface of the water. After some time, the bait was thrown on to the reef itself, and after several times seizing bait which had been swept back by the receding wave, on several occasions one of these fishes actually came over the reef in the surge of the wave in pursuit of a piece of bait, seized this, and returned to deeper water before the wave had subsided.

That this species will perform a feat of this nature is evidently well known. One angler has reported having seen one of these fishes actually left stranded on an isolated rock by one wave, and returning to the water by the next. Another who had noticed these fishes passing over a rock in the surges of the waves states that he actually hooked a fish by casting his bait on to the rock itself. In the Eastern Province of South Africa this species is frequently taken by anglers in the surf at high tide, being often actually hooked on a spot which at low tide would be above the level of the water. From this characteristic has resulted the Eastern Province

name of "Highwater." It has been observed that when this species is hooked in relatively shallow water over broken rocky ground, it will occasionally jump clear of the water, more often than not thereby freeing itself from the hook.

This species appears to feed very largely upon the common mussel (*Mytilus edulis*), the intestinal residues generally consisting chiefly of crushed mussel shells. The stout anterior teeth of the "Galjoen" are admirably adapted for wrenching or twisting shellfish from the rocks, and these mollusca are doubtless crushed between the pharyngeals, which bear heavy crushing molariform teeth (Pl. XVII, D and E). Seaweeds also at times form a large part of the diet of this species.

Ordinary "Red-bait" is the common bait employed on lines, but large specimens have also been taken on fish bait, as well as on "Sea-cat" (*Polypus* sp.).

It may be noted that in areas much frequented by anglers this species has diminished most markedly in numbers within the last thirty or forty years, so that where large catches were at one time of common occurrence, the capture of even a single specimen may now be an event. On the other hand, in places difficult of access and so rarely fished, it is still possible to catch large numbers of these fishes at any normal time. There is every indication that this species moves within a comparatively restricted area, so that intensive fishing may well produce a local scarcity.

The spawning habits of this species are unknown. It is curious that the specimens examined have all been immature males. It might be suggested that anglers in the Western Province should examine fishes caught in the winter months and forward specimens of ripe females to the South African Museum.

Dichistius falcatus n. sp.

(Plates XIV and XVII.)

Body ovate, fairly compressed, maximum width 1·6 in head. Dorsal profile gently curved, interorbital prominence very slight, snout little steeper below.

Depth 2·0–2·1, length of head 3·0–3·3 in length of body. Eye 4·3–5·0, snout 3·0–3·3, interorbital 2·5, postorbital part of head 1·7–1·8 in length of head. Preorbital uniformly deep, depth above end of maxilla 6·0–6·6 in head. The distance from the upper margin of the sheath at the base of the fourth dorsal spine to the nearest point of the lateral line is equal to or less than the postorbital part of the head.

Mouth terminal or even occasionally sub-inferior, slightly oblique, maxilla extends to below anterior border to first third of eye, extremity not covered. Distance from hind margin of maxilla to upper margin of upper lip at snout tip 1·7–1·9 in postorbital part of head. Upper lip deep and fleshy, depth at snout apex 1·8–2 in eye. 20–24 compressed rather elongate incisiform teeth in a single row in each jaw, anterior subtruncate, lateral

teeth more acute. Two series of about eight each of similar but much smaller teeth behind the outer series in each jaw, concealed in fleshy pads. Palate and tongue edentate.

Gill-membranes united forming a fold across the throat, narrowly united below with isthmus. Gill-rakers 5–6 + 13–14, 2–2·5 in gill-filaments, which are 1–1·1 in eye.

D X, 19–20, inserted above slightly nearer pectoral than ventral base, deeply notched. Spines fairly stout, heteracanth, fold into deep scaly sheath. First spine 10–12, 2nd 4·3–4·5, 3rd 2·5–2·6, 4th 2·1–2·2, 5th 2·0–2·1 in head, thereafter shorter to the 9th. Soft rays anteriorly elevated, falcate or subfalcate, edge of fin deeply concave. The tip of the lobe when depressed usually reaches above beyond the apex of the depressed last anal ray, and extends beyond the apex of the 10th dorsal spine 1·5–1·7 in head, usually longer than postorbital part of head. Base of soft dorsal shorter than head.

A III, 13–14, inserted below slightly before origin of soft dorsal, spines moderately stout, first 5·5–6, 2nd 3·3–3·5, 3rd 4·0–4·3 in head. Soft rays anteriorly elevated forming a subfalcate lobe, which extends 1·6–1·7 in head beyond the apex of the 3rd anal spine, edge of fin deeply concave. Base of soft anal 3 in depth of body.

Pectorals 3·6–3·8 in length of body, tip reaches almost below origin of soft dorsal.

Ventrals 4·0–4·5 in length of body, apex reaches, or almost reaches, base of first anal spine.

Caudal moderately forked, peduncle 1·1–1·2 times as long as deep. Least depth of peduncle 3·0–3·2 in depth of body, 6·6 in length of body.

Scales ctenoid, somewhat larger on posterior part of body, generally larger below lateral line than above. Lateral line gently curved, lateral rows 73–78, tubules about 65, 28–30 above lateral line obliquely back from base of first dorsal spine. About 50–60 predorsal, and about 25–30 on cheek to preopercle edge. Whole body and head, except muzzle, scaly. Median fins densely scaly, on soft dorsal and anal posteriorly scaling scarcely extends more than half length of membrane. Scaly sheath of spinous dorsal continued along basal portion of alternate spines. Pectorals scaly three-fourths. Ventrals with outer rays only scaly.

Colour.—Dark brown to black with or without 8–10 darker cross bars about equal to eye, wider than interspace, first over nape, last on peduncle. Fins black, caudal dusky. Iris bronzy.

Length.—Up to 400 mm.

Locality.—Knysna, Port Alfred, Great Fish Point, Cove Rock (East London), Transkei Coast.

Type from Great Fish Point (Pl. XIV) in the Albany Museum. Seven specimens from 200 mm. up examined.

This species is admittedly very close to *capensis* and was separated only after long and detailed study. It is possible that specimens may ultimately be obtained which will show complete transition between the two forms here recognised.

Nevertheless the form of *falcatus* is characteristic of the coast of the south-eastern Cape, and after brief study there is no difficulty in distinguishing it from *capensis*. All the fins are markedly longer, even the spinous dorsal, the mouth is slightly larger, and always extends to the eye, while the shape of the snout is characteristic, being more rounded. Further, this species is more often taken with cross bars than *capensis*, and the silvery colour phase occasionally found in that species is apparently very un-

common, or unknown, in *falcatus*, most specimens being very dark in colour.

It appeared at one time as if sexual dimorphism might account for the difference between *capensis* and *falcatus*, since all my specimens of the former appeared to be males, and most of the latter, with the exception of one or two too immature or decomposed for positive determination, females. Nevertheless, this hypothesis is scarcely tenable, since to my knowledge the form of *falcatus* does not occur near the Cape Peninsula, while *capensis* grows to a larger size than that species, which would be remarkable if *capensis* proved to be the typical form of the male.

The habits and environment of *falcatus* are very similar to those of *capensis*, except that the former appears to prefer less turbulent water, being generally taken from deeper water in gullies or on reefs. The chief food appears to be the common mussel, together with occasional small crustacea and seaweeds.

In some respects *falcatus* appears to fall midway between *capensis* and *multifasciatus*, and has probably contributed to the non-recognition of the latter. It is well differentiated from *multifasciatus* as very brief study shows.

Ripe females of *falcatus* are taken on the coast of the Eastern Province chiefly during August. The eggs are pelagic, very numerous, and less than 1 mm. in diameter.

Dichistius multifasciatus (Pell.).

(Plates XV and XVI.)

"Kolayeleetye"; "Ntombiyeleetye." (Native names.)

1914. Pellegrin, Bull. Soc. Zool. Fr., vol. xxxix, p. 231.

1925. Fowler, Proc. Ac. Nat. Sci. Phil., vol. lxxvii, p. 233. (*Dipterodon capensis* C. and V.)

1927. Barnard, *loc. cit.*, p. 635. (*Dipterodon capensis* C. and V., part.)

1933. Fowler, Bull. U.S. Nat. Mus., vol. xii, p. 216. (*Coracinus capensis* C. and V.)

1934. Fowler, Proc. Ac. Nat. Sci. Phil., vol. lxxxvi, p. 476, fig. xlii. (*Drepanoscorpis gilchristi.*)

Body deep, margins subangular, very compressed, maximum width 1·8–2·0 in head, 3·0–3·3 in depth of body. Dorsal profile of snout fairly steep, in a more or less even curve from first dorsal, with very slight interorbital prominence.

Depth 1·8–1·9, length of head 3·0–3·2 in length of body. Eye 4·0–4·3, snout 2·8–3·0, interorbital 3·1, postorbital part of head 1·8–1·9 in length of head. Preorbital uniformly deep, depth above end of maxilla 5·3–5·6 in head. The distance from the upper margin of the sheath at the base of the fourth dorsal spine to the nearest point of the lateral line is 1·15–1·2 times the postorbital part of the head.

Mouth moderate, terminal, slightly oblique, maxilla extends to below nostrils or to below anterior part of orbit, extremity not covered. Upper lip rather deep and fleshy,

depth at snout apex 2·3–2·5 in eye. 30–34 elongate teeth in single outer series in upper jaw, anterior more or less truncated, posterior more slender and acute. Two series of similar but much smaller teeth behind the outer, concealed in fleshy pads, and very fragile. Similar teeth in lower jaw. Palate and tongue edentate.

Gill-membranes united forming a moderate fold across the throat, narrowly united with isthmus below. Gill-rakers moderate, 5–6 + 14–15, 1·8–2·2 in gill-filaments, which are 1·2–1·3 in eye.

D X, 21–23, inserted above nearer base of pectoral than base of ventral, deeply notched between spinous and soft portions. Spines stout, heteracanth, fold into deep scaly sheath. First spine 10–15, 2nd 4·5–6, 3rd 2·6–3·2, 4th 2·2–2·5, 5th 2·2–2·4 in head, thereafter graduated shorter. Soft rays anteriorly elevated forming a short blunted or pointed lobe not falcate, which extends beyond apex of 10th spine much less than length of postorbital part of head. Base of soft dorsal longer than (1·1–1·2 times) head. The tip of the depressed anterior rays scarcely reaches beyond the base of the last anal ray.

A III, 13–14, inserted below the origin of the soft dorsal. Spines stout, first 5·6–6·0, 2nd 3·3–3·5, 3rd 4·0 in head. Soft rays anteriorly elevated, slightly longer than dorsal rays. Lobe extends 1·9–2·1 in head beyond apex of last anal spine. Edge of fin deeply concave. Base of anal 2·7–3 in depth of body, greater than postorbital.

Pectoral 3·5–3·8 in length of body.

Ventrals 3·7–4·0 in length of body, apex usually reaches well beyond the base of the first anal spine.

Caudal moderately forked, peduncle 1·2–1·3 times as long as deep. Least depth of peduncle 3·9–4·1 in depth of body, 7·4–7·6 in length of body.

Scales ctenoid (Pl. IV, A) somewhat larger on posterior part of body. Lateral line scales largely concealed, smaller than adjoining scales, tubes simple (Pl. IV, B). Lateral line gently curved. Lateral rows 83–86; tubules about 70, but almost impossible to count with accuracy; 28–31 above lateral line, counted backwards from base of first dorsal spine. About 50–55 predorsal, and about 20 on cheek to edge of preopercle. Whole body and head scaly, except snout in advance of nostrils, anterior part of preorbitals, and chin. Median fins densely scaled. On soft dorsal and anal scaling extends at least $\frac{3}{4}$ of length of membrane, even of posterior rays, and is very dense. Pectorals scaly for proximal three-fourths. Ventrals similarly between outer rays. Bases of alternate dorsal spines scaly.

Colour.—Light silvery brown, with seven darker cross bands about equal to light interspace, equal to or wider than eye; between each pair a much narrower stripe. First bar over nape, last over peduncle. Head dark. Membrane of spinous dorsal black, hinder margin lighter. Hind margin of caudal black. Anal spines light, soft fin dark. Ventral spine light, distal $\frac{3}{4}$ of fin dark. Pectoral dark distally. Iris bronzy.

Length.—Up to 285 mm.

Locality.—Knysna (Juvenile 55 mm.); Great Fish Point; East London to Durban; Madagascar (Type locality).

The body shape of this species is characteristic (Pl. XV), and enables it to be identified at a glance even in preserved or dried specimens from which all trace of marking has faded. The heavy scaly investment of the median fins prevents much movement of the rays, and in those specimens I have examined the dorsal and anal rays have remained fully erect.

This is a much more uniform species than *capensis*, and in so far as I am aware, unbanded specimens are never encountered. The alternate

wide and narrow bands are very characteristic, and very vivid in the live fish, or in fresh specimens.

There can be no question of the validity of *multifasciatus*, and it is remarkable that subsequent workers should have rejected Pellegrin's perfectly plain diagnosis of the differentiation from *capensis*. The very shallow peduncle and the long base of the soft dorsal are immediately diagnostic, even in juveniles, as are in effect also the body shape and markings.

Fowler (*loc. cit.*) stated that *Drepanoscorpis* has only a single series of teeth. The two inner series of teeth are actually very easy to overlook, being concealed within fleshy pads, and the teeth are small and fragile. They are incisiform, and not conical in shape, as usually stated. There are several inconsistencies between the description and figure of *gilchristi* (*loc.cit.*).

D. multifasciatus is rarely if ever encountered west of Algoa Bay. A single small specimen was taken in a rock pool at Knysna.

This species does not appear to grow as large as the other two, 300 mm. apparently being an outside length.

In so far as can be ascertained, it is unusual for *multifasciatus* to be captured on lines at the same time as the other species or under equivalent conditions. The latter may be taken in broken water, relatively shallow, on sandy as well as rocky bottoms, whereas *multifasciatus* appears to prefer exclusively rocky haunts and clearer water, being generally taken in deeper water, often in gullies at low tide. It has been noticed that when this species is taken, other fishes, especially larger fishes, are generally absent.

On the eastern coast of South Africa, where all three species may be found, the flesh of *multifasciatus* is generally regarded as superior to that of the others, being lighter in colour and of less pungent flavour. The natives of this area constantly distinguish *multifasciatus* from *falcatus* (known as "Damba") by names indicating its fondness for rocky haunts. The two native names mean "Pick up a stone" and "Stone-maiden."

I wish to express my gratitude to Dr. Barnard, of the South African Museum, for the loan of material. To numerous friends, especially J. Rex Meterlerkamp, Esq., of Knysna, for valuable assistance rendered in securing material. Also to the South African Research Grant Board (Carnegie Fund) for generous financial assistance.

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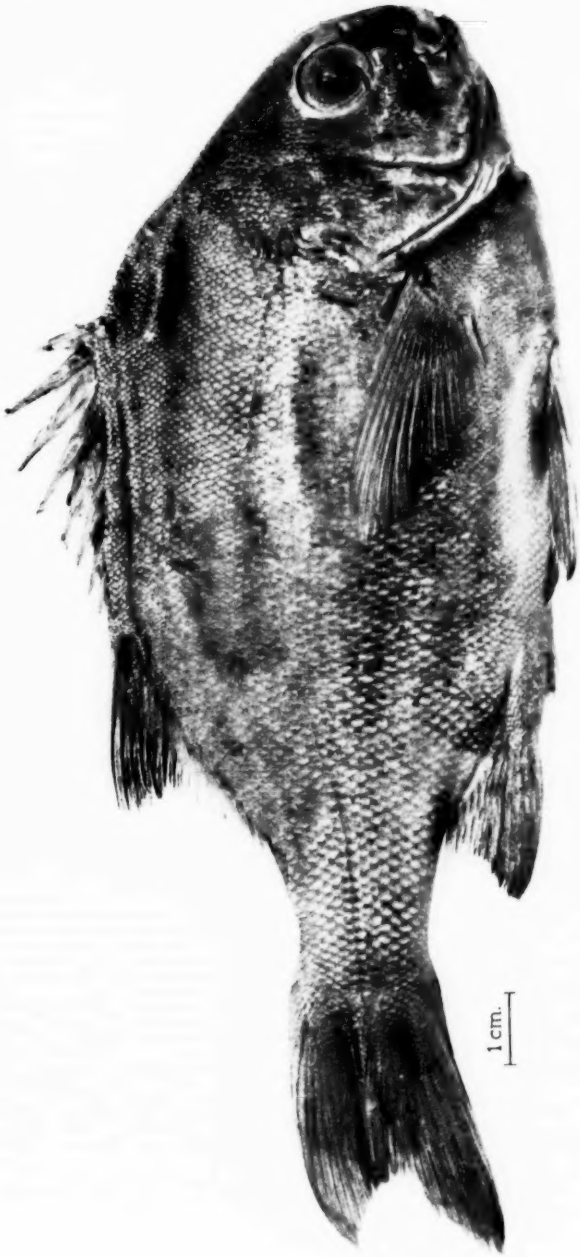
Albany Museum,
Grahamstown,
April 1935.



Derbistius capensis (C. and V.) (Juvenile).

Dichistius falcatus n. sp. (Type).

J. L. B. Smith. Neill & Co., Ltd.

Dichistius multifasciatus (Pell.).

J. L. B. Smith.

Neill & Co., Ltd.

Scales of *Dichistius multifasciatus* (Pell.).

A. 24th lateral scale adjacent to lateral line.

B. 20th lateral line tubular scale.

From specimen 230 mm. total length. The line below each scale represents 1 mm.

J. L. B. Smith. *Neill & Co., Ltd.*

Dichistius falcatus n. sp.

A. Preopercle. B. Anterior dorsal spines. C. Mandible from behind: the line indicates posterior teeth. D. Middle upper pharyngeals.
E. Lower pharyngeals. F. Maxilla. G. Premaxilla. From specimen 285 mm. length.

SOME PREHISTORIC SKELETAL REMAINS FROM THE NATAL COAST.

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(With Plates XVIII–XX and four Text-figures.)

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1. Introduction.

The knowledge of Natal Coast prehistory has developed only within the last few years, through the studies of Chubb and King (1932), Brien (1932*a*, 1932*b*), and Cramb (1934). These investigators have established the presence of three successive cultures: a Middle Stone Age of Stillbay type with certain local peculiarities; a Late Stone Age of Smithfield type, also with definite local peculiarities, followed by a recent period with evidence of iron-working, and associated with a pottery which is characteristic of the Natal Coast area (Chubb and King, 1932) and has a Bantu facies.

Skeletal material from this area has for some time been filtering into various collections. Chubb and King (1932) enumerated the skeletal finds known to them up to that date. Brien (1932*b*) obtained from a Late Stone Age horizon in the Isipofu cave two human fragments, a molar tooth and a second lumbar vertebra. These were examined by Wells (Brien, 1932*b*), who concluded that this evidence, though scanty, pointed to the existence of a Boskopoid type of man in this area during the Late Stone Age.

The Karridene Skull (Galloway and Wells, 1934) has since confirmed this supposition. This specimen, obtained from a Late Stone Age horizon, was of Bush type with marked Boskopoid features, and possible indications of another, but undetermined, racial strain. Evidence that the Boskopoid type persisted even into the period of iron-working and pottery manufacture was also forthcoming. Two skeletons from Tinley Manor, belonging to this last period, combine strong Boskopoid and Bush features with a Bantu element (Wells, 1934).

From these studies the inference appeared warranted that the Late Stone Age population of the Natal Coast, like that of the Cape Coast, was a

Bush-Boskopoid admixture. Further, this type seemingly persisted into the iron- and pottery-using post-Smithfield period, despite the influx of the Bantu. The purpose of the present paper is to test the validity of these inferences by examining considerable additional material assembled from this area.

For this survey remains of six individuals were available. Three came from the collection of the Durban Museum, through the courtesy of the Director, Mr. E. C. Chubb. These comprise—

(1) A juvenile skull with mandible, from a midden deposit at St. Lucia Bay;
(2) Portions of a fossilised skeleton exhumed at Doonside, not associated with any cultural relics;
(3) An incomplete skull found in a sand-dune near the Durban Country Club, also without cultural associations.

The remaining three specimens comprised—

(1) An incomplete skull with mandible and a right humerus, from a midden deposit at Illovo Beach, loaned from the private collection of Mr. P. G. Brien of Durban;
(2) A juvenile mandible from a midden deposit at Umhloti, placed at our disposal by Dr. N. L. Murray; and
(3) An extremely fragmentary skeleton from a midden deposit at Umgababa, included in the anthropological collection of this Department (No. A247).

In the description of these specimens attention has been specially directed to those features which, in the experience of workers in this Department, have been found to be of greatest value in the racial diagnosis of South African skulls.

2. Description of the Skeletal Material.

(a) *St. Lucia Skull,*—The circumstances of the discovery of this specimen are reported by Chubb and King (1932). It is the skull of a young individual of about eleven years. Owing to the great distortion, measurements and indices lose a great deal of their diagnostic value.

The skull is definitely dolichocephalic and has a cranial capacity of 1230 c.c. Plate XVIII shows how closely its ovoid cranial form corresponds with that of a typical Bantu skull. The contour of the norma lateralis (fig. 1) is typically Bush.

The inferior frontal eminence and mons temporo-sphenoidale are prominent. The root of the zygoma is slender. The glenoid fossa has a large antero-posterior diameter and its articular surface occupies the whole of the anterior surface of the massive tympanic plate. The parieto-squamal

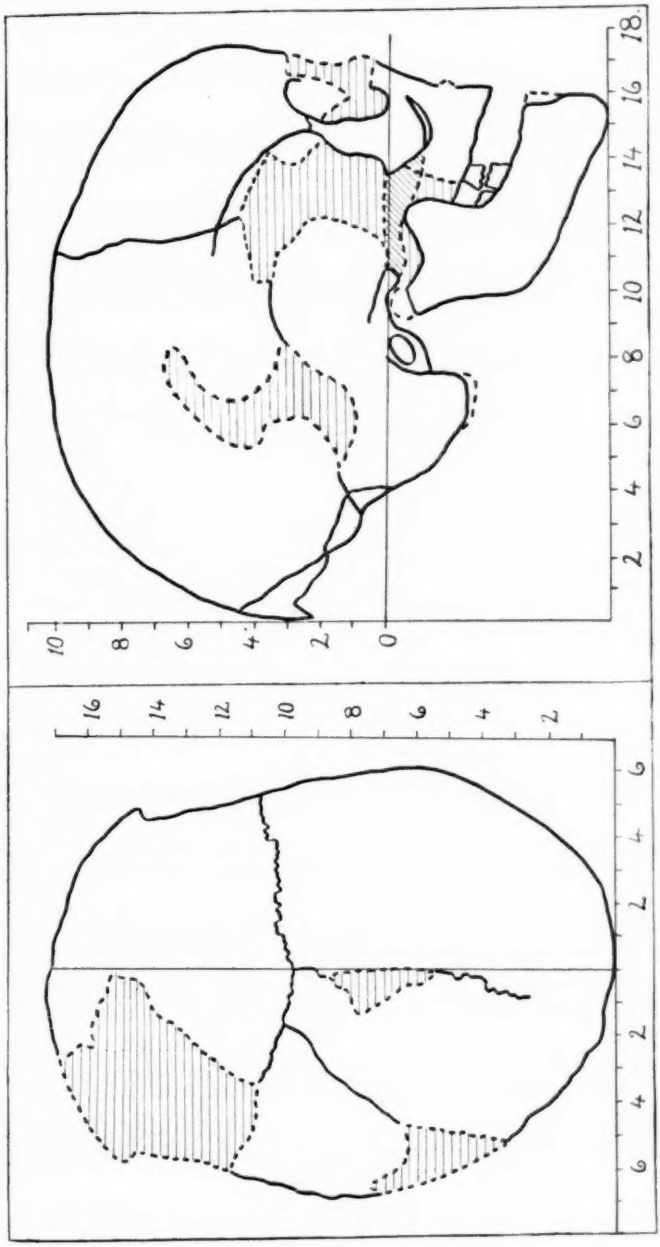

FIG. 1.—St. Lucia skull. Tracings of norma verticalis and norma lateralis.

bulge, found in the juvenile Bush type, is well marked on the right side. The mastoid processes are deficient, but the remnants indicate that they were small and slender. The supramastoid ridge and groove and the sternomastoid crest are poorly defined. The external angular process of the frontal bone resembles that of the Illovo skull (to be described later), but the peculiarities are not so exaggerated.

The frontal bones show an incipient ophryonic furrow. The glabella and superciliary ridges are well defined for an immature skull. The supra-orbital margin is sharp in its outer half. The orbits are square in shape and show an orbital shelf. The body of the maxilla is only slightly scooped out and its frontal process has the typical inflated Bush appearance. The nasal cavity is mesorrhine.

The ascending ramus of the mandible is relatively low and rhomboidal in outline. It is set obliquely to the body. The angle is inverted. The body is low and excessively thick. Its upper and lower borders are approximately parallel. There is a slight mental protuberance. The symphyseal region is fragmented but must have been almost vertical. The vertical direction of the dental sockets negative the possibility of any alveolar prognathism.

The mandible bears two erupted molars and an unerupted second premolar on the left side and a first molar on the right side. The cusp pattern, the primitive arrangement of a second molar being larger than the first, and the peculiar order of eruption of the second molar before the second premolar are pathognomonic of the Bush race.

From the foregoing description it will be seen that the cranium of the St. Lucia skull has a preponderance of Bantu features, while the characters of the mandible are almost essentially those of the Bush type.

This St. Lucia individual is a Bantu-Bush admixture, a conclusion which differs from that reported by Chubb and King (1932) who state: "The skull has been examined by Dr. R. Broom, and he is of the opinion that it is neither Bushman nor Bantu, but belongs to the brachycephalic pre-Bushman race that he terms the Korana."

From my measurements the skull from St. Lucia is dolichocephalic, and even allowing for the fact that it belongs to a young individual it shows none of the primitive features which Broom lays down as distinctive of the "Korana." From my analysis I can come to no other conclusion than that it is a Bantu-Bush hybrid.

(b) *The Umhloti Mandible.*—This fragment, obtained by Dr. N. L. Murray, from a shell-midden at Umhloti, about 15 miles north of Durban, was associated with the same characteristic decorated pottery as was obtained from the Tinley Manor midden. The bone shows a very slight degree of mineral mineralisation.

The specimen comprises the greater part of the body on both sides; the rami are missing. The first permanent molars and first permanent incisors are fully erupted, but the lateral deciduous incisors are still in position. The age of the individual was therefore about seven years, the same as that of the juvenile specimen from Tinley Manor.

This mandibular fragment has been compared with the Tinley Manor juvenile mandible and with the mandible of a seven-year-old Bantu (fig. 2).

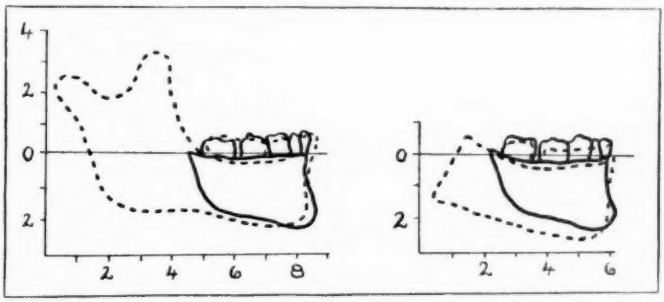

FIG. 2.—Tracings of the Umhloti mandible superimposed on the mandible of a Bantu child aged 7 (left), and superimposed on the Tinley Manor juvenile mandible.

The fragment appears to be much more slender than the Tinley Manor juvenile mandible. The general proportions of the body agree very closely with those of the seven-year-old Bantu mandible. The form of the symphysis, however, differs widely from that of the Bantu and to a less extent from the Tinley Manor specimen. Compared with the Bantu there is a less degree of alveolar prognathism, while the mental protuberance is very well defined and much more salient. Indeed, the mental protuberance of the Umhloti mandible is more pronounced than that of Bantu mandibles, in which the lateral incisors are already fully erupted, and is comparable with those of juvenile European mandibles. However, in the Umhloti mandible there are no bilateral mental tubercles such as are present in the European mandible as early as the fifth year.

The mental protuberance of the Tinley Manor mandible was also more pronounced than that of the Bantu at this stage. In the Umhloti mandible the mental protuberance is actually slightly more projecting than that of the Tinley Manor specimen and has a more sharply defined appearance which is accentuated by the slenderness of the body.

The dental arcade is wider than that of the Bantu mandible. The cusps of the deciduous and permanent molars are closely similar to those of the Bantu, in contrast with those of the Tinley Manor mandible which are of the more primitive configuration seen in the Bush mandible. The posterior

aspect of the symphysis bears a genial fossa, a common feature in Bush mandibles.

The proportions of the body and the character of the teeth indicate a strong Bantu element in this specimen, but the genial fossa is a definitely Bush feature. The extremely salient mental protuberance cannot be employed as a diagnostic character. Such a prominence has not been found yet either in a Bush or Bantu mandible at this stage of development. It is, however, possible that when a sufficiently large series of immature mandibles is available the degree of prominence shown by the Umhloti specimen may prove to be within the Bantu range.

(c) *The Illovo Skeleton.*—This very important skeleton was obtained from a shell-midden at Illovo Beach, about 22 miles south of Durban, and not far distant from the Karridene site where the Karridene skull (Wells and Galloway, 1934) was found.

The remains consist of the frontal and facial portions of the skull, still articulated, the mandible, and the right humerus. They show only a very slight degree of mineralisation, in this respect resembling the Tinley Manor and St. Lucia specimens. The individual is an adult, but not of advanced age. The sex cannot be determined with certainty from the portions present, but certain features suggest that it is male.

The Skull—Norma Lateralis.—The glabella and superciliary eminences are slightly projecting and are separated from the frontal bosses by a distinct ophryonic groove. The transition from the forehead to the vault is relatively abrupt. The contour is Bush. On the left side there is a slight inferior frontal eminence and an indication of a distinct mons temporo-sphenoidale.

The external angular process is a prominent truncated inverted-triangular piece of bone (Plate XIX). Its infero-medial margin, forming the lateral two-thirds of the superior orbital margin, is slender and overlaps the orbital cavity, thereby increasing the depth of the lacrimal fossa. This flange of bone is responsible for the fact that the line of the superior orbital margin is an almost straight one from the supra-orbital notch to the fronto-malar suture. The posterior margin is almost vertical and curves slightly in a posterior direction to join the temporal line.

The process is 37 mm. wide—that is, measured from the fronto-temporale to the supra-orbital notch—and it is 11 mm. wide where its truncated apex forms the fronto-malar suture.

The zygomatic process of the malar shares this massiveness. Its posterior border is vertical, and the absence of the tubercle on this border gives it a primitive appearance. The massiveness of external angular process and zygomatic process contrasts markedly with what usually obtains in the Bush skull (Plate XIX).

Norma Facialis (Plate XIX).—The frontal region is narrow. The frontal bosses are infantile in character and there is a distinct metopic ridge. The glabella and superciliary eminences are well moulded but not very projecting. The supra-orbital triangle is excavated, giving an everted appearance to the lateral part of the inferior orbital margin. Foramina for the branches of the supra-orbital nerves are present at a distance of 12 to 18 mm. from the orbital margin, but there are no grooves produced by these nerves. The massive zygomatic processes of the frontal bone do not project far laterally, the bi-orbital diameter being only 7 mm. greater than the least frontal. The unusual characters of the external angular processes are again demonstrated in this norma.

The face is chamæprosopic, having an index not greater than 48·4. The orbits are of medium height; they are rectangular in outline and obliquely placed, resembling those of the Boskop skull from Zitzikama. The Boskop orbital shelf of Keith is well marked. The inter-orbital space is 26 mm. The nose is very broad and nasal gutters are present. The infra-orbital region is slightly excavated; there is a distinct canine fossa. The infra-orbital foramen is far below the orbital margin, more so than in Bush and Bantu. The alveolar region is massive.

The malar region is distinctive. Usually the plane of the malar bone is approximately parallel with the sagittal plane and faces lateralwards. It is convex and the greatest bi-malar diameter lies between two points in the bodies of the bones. In this skull the plane of the malar bone lies obliquely to the sagittal plane and faces antero-laterally and somewhat upwards. The surface is not convex but flat, and there is a difference of 1·5 cm. between the bi-orbital diameter and the greatest bi-malar diameter which is *between points on the inferior margin of the bones.* The obliquity of the plane of the malar is so marked that fronto-temporale, the lateral margin of the fronto-malar suture, and the inferior margin of the malar are on the same straight line (Plate XIX).

Norma Basalis.—The dental arch is very slightly horse-shoe shaped; the maxillo-alveolar index is 111·1. The molar teeth show interproximal and occlusal attrition. The palate is moderately deep and slightly shelving in its anterior fourth. There is a definite torus palatinus. The palatal surface is covered with irregular spicules of bone.

The Mandible.—The ascending ramus is relatively low and broad. The sigmoid notch is shallow. The coronoid process is very broad and its tip lies well below the level of the condyle, much more so than is typical for the Bush mandible. The angle is not everted, but there is a slight ridge along the lower margin of the ramus. The body is low but not excessively thick; its upper and lower borders are nearly parallel. There is an ill-defined mental protuberance overshadowed by distinct alveolar prognathism.

On the internal surface of the symphysis there is a genial fossa, and below this a horizontal shelf or ridge such as was described in the Karridene specimen.

The Humerus.—The humerus is short and stout. The prominences for the insertion of the deltoid and pectoralis major are developed to an extent which, even in primitive races, is found only in the male. A very primitive feature of this bone is the presence of a backward concavity in the proximal half of the shaft, as well as a forward concavity in the distal half. The axis of the shaft thus describes a sigmoid curve. Another primitive feature is the high angle of torsion; this exceeds even that of the Bush humerus. The olecranon fossa is not perforated.

Stature.—Calculation from the length of the humerus by various formulæ gives a stature of 1432 mm. (4 feet 8 inches). It must be borne in mind that if the individual had disproportionately short arms, as in the Bush type, the true stature might be 1–2 mm. more. Even allowing for this, it is clear that this individual was of dwarfish Bush stature.

The features of this specimen which are of value in racial identification are almost all of Bush or Bush-Boskopoid type. The prognathism of the jaws may possibly be regarded as a Bantu character, but no other Bantu traits are recognisable. In its Bush-Boskopoid nature this individual therefore agrees with the Karridene and Tinley Manor specimens.

(d) *The Doonside Skeleton.*—This specimen (Durban Museum, No. 3062) was found at Doonside, about 20 miles south of Durban. This site is very close to the Karridene and Illovo sites. The finder, Mr. V. Thorne, reported that it lay at a depth of 4 feet 6 inches below the surface of the ground, at a spot about a quarter of a mile inland. The posture of the skeleton is not recorded and no objects were found associated with it.

The remains submitted for examination comprise the skull, a portion of the mandible, the innominate bones, the femora, the fibulae, the left tibia, and the right humerus. They are appreciably fossilised, and retain traces of a reddish sandy matrix similar to that in which the Karridene skeleton was embedded. It is a fully adult skeleton but not of advanced age.

The Skull.—This is almost complete, lacking portions of the base and the left side of the face and braincase. The cranial capacity is approximately 1500 c.c. and is therefore macrocephalic, exceeding not only the Bushman but also the Bantu average. For a female skull such a capacity is remarkable and must be regarded as Boskopoid. This high capacity results from the relative breadth and height of the skull. The cephalic index falls only just below the lower limit of brachycephaly. It is *hypsi-pentagonoid* and resembles the Karridene skull in combining the Bush type of cranial outline with a relative height much greater than that of the Bush skull.

Norma Verticalis (fig. 3).—The parietal bosses are extremely prominent, the outline in this norma falling into the *pentagonoides acutus* sub-group.

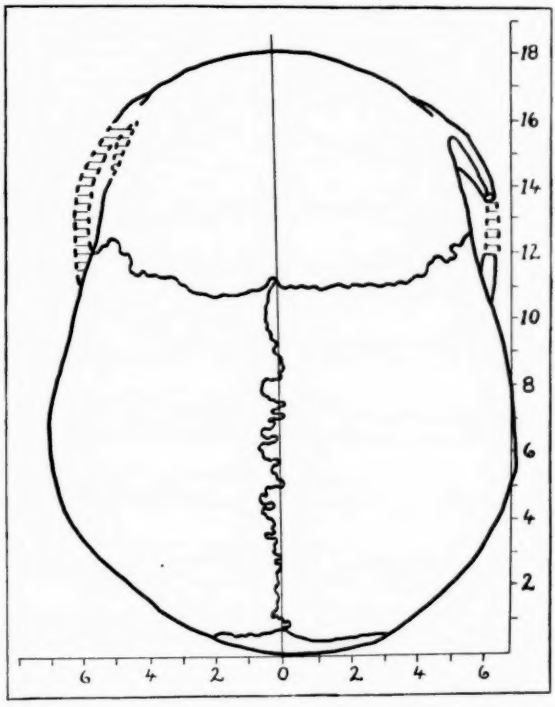

FIG. 3.—Tracing of norma verticalis of the Doonside skull.

The fronto-parietal index indicates a degree of frontal narrowing similar to that shown by the Karridene skull. The frontal bosses are infantile in development. There is evidence of a slight metopic ridge. The glabella and superciliary eminences are concealed in this view by the frontal portion of the braincase. There is a slight projection of the infra-orbital and alveolar regions. The skull is phænozygous.

There is a distinct indication of the Boskopoid bilateral post-coronal depression. A slight interparietal groove is also present. The occiput is tapering. The sutures of the vault are all completely patent.

Norma Lateralis.—The appearance of the skull from this aspect is shown in fig. 4 and Plate XX. The glabella and superciliary eminences are well moulded but have very little projection. There is a well-marked

transverse ophryonic furrow separating these eminences from the frontal bosses. These last project forward considerably in front of the plane of the glabella. The contour of this part of the frontal bone is closely similar to that of the Boskop skull B.Za.2 from Zitzikama, which, like the Doonside skull, is regarded as a female.

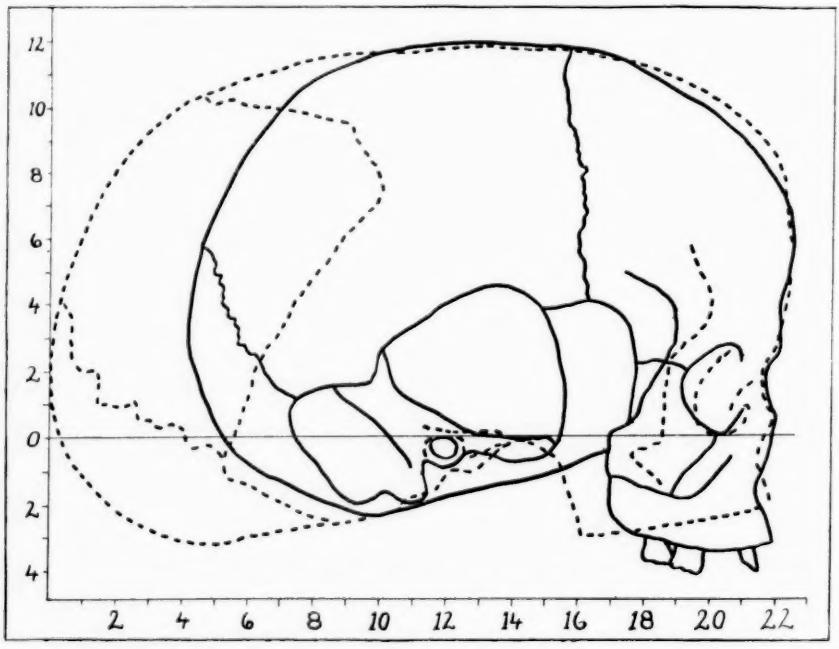

FIG. 4.—A superimposition of the contour tracings of the Doonside skull and the skull B.Za.2 from Zitzikama.

The cranial contour is similar to that of the Karridene skull except that at the level of the parietal boss the contour turns sharply downwards and the projection of the occiput is accentuated by a slight depression at lambda. There is a ridge along the superior nuchal line which is separated by a shallow transverse groove from the prominent cerebellar fossae.

The diminutive mastoid processes are narrow antero-posteriorly and do not extend downwards below the plane of the cerebellar fossae. The digastric groove opens out on to the lateral aspect of the skull. There is a powerful sternomastoid ridge, and a very well-defined supramastoid groove separates this from the markedly Boskopoid supramastoid crest.

The tympanic ring is slender and the post-glenoid tubercle small. The root of the zygomatic process is stout.

There is only a slight indication of the *mons temporo-sphenoidale*. The inferior frontal eminence is well defined.

The face is short and shows generalised prognathism. The orbits are low and the nasal profile flat.

Norma Facialis.—The frontal region is arched but shows no metopic ridge. The frontal bosses are not prominent. The glabellar prominence is situated very low down, below the plane of the superior orbital margin. From its extremities a broad low convex ridge passes upwards on either side to the supraciliary eminences. The supra-orbital triangle is hollowed out, giving the everted appearance of the superior orbital margins. The zygomatic processes of the frontal bones are stout, but do not project far laterally.

The face is incomplete but is clearly very short and broad. The orbits are small in proportion to the face. They are low, rectangular in outline, and set very obliquely, agreeing in all these features with that of the Zitzikama Boskop skull (Gear, 1926). Further, the orbital shelf is extremely well developed in this skull. The interorbital interval is 21 mm. The nasal bones are moderately broad with no median ridge.

The preserved portions of the nasal aperture indicate an extremely platyrhine nasal index. This is in agreement with known Bush skulls. There is, however, an indication of a nasal gutter, which is not regarded as a Bush feature. The zygomatic process of the maxilla is very deep. Its inferior border joins the alveolus just below the level of the nasal floor. There is a shallow infra-orbital depression but no distinct canine fossa. The contour of the skull is identical with that of the Zitzikama Boskop skull (Gear, 1926). The supramastoid and sternomastoid ridges are prominent in this norma, but the mastoid process is not conspicuous. The tip of the mastoid process does not project below the plane of the well-filled cerebellar fossae. The occipital boss is slightly projecting.

Norma Basalis.—The muscular impressions on the nuchal plate are well defined. The mastoid processes are tapering and are flanked by deep and narrow digastric fossae. The groove for the occipital artery is prominent and very wide. The temporo-mandibular articulation has the very characteristic Boskopoid form (Gear, 1926).

The dental arcade is horse-shoe shaped. The third molars, which are fully erupted, are reduced in size. The teeth, especially the first molars, are extremely worn, but there is no interproximal attrition.

The Mandible.—The incomplete mandible is essentially of Bush form.

The Humerus.—This is of the short, slender female Bush type. The most remarkable feature of the bone is the high angle of torsion, which

even surpasses that of the Bushman and must be regarded as extremely primitive. The distal articular surface also has a form which is considered to be primitive.

There is no perforation of the olecranon fossa.

Innominate Bones.—Neither of these is complete, but the two between them preserve all the parts of the bone except the symphysis pubis and the ischio-pubic ramus. The innominate bone is remarkably high and narrow, giving an innominate index even less than in the Bush race, the innominate bones of which are regarded as very primitive in their height and narrowness (Orford, 1934).

The bones are small in size, agreeing with those of the Bush race but are much more massive. Such massiveness is described by Gear (1925) as a feature of the innominate bone of Boskop man. The curvature of the iliac crests and the form of the iliac blade agree with those of Bush female skeletons. The form of the sciatic notch is not distinctively female; however, the position of the sacro-iliac articulation in relation to that notch is such as is found in Bush females.

The ischial portion of the bone, though massive, is essentially Bushman in its structure. The acetabular articulation is deeper than in the Bush pelvis, but has the same primitive anterior direction that is found in the Bush type. The obturator foramen, so far as can be estimated, has the form and proportions seen in Bush females.

Femur.—The shortness, the stoutness, and curvature of the shaft and the stoutness of the head and neck are female Bush in type. The angle of torsion in this bone as in the humerus is unusually large, exceeding the average for the Bush type, which is primitive in its large angle of torsion. The muscular markings on the upper portion of the bone are powerful, as in the Bush femur. There is a slight indication of a third trochanter with a distinct hypotrochanteric fossa.

The platymeric index is not as low as is usual in the Bush race, approximating to the values found in the Bantu and European. The pilastric index is less than that of the Bush femur, but not so low as in the Bantu and European. The markings around the lower end of the bone agree in detail with those of the Bush femur.

Tibia and Fibula.—These bones also are short, corresponding with those of Bush females. The fibula is slightly stouter than is usual in the Bush race; it shows no other characters which can be used for racial diagnosis.

The tibial tuberosity and other impressions on the upper end of the tibia are well developed, even exceeding those of the Bush type which is characterised by the great development of these features. The angle of retroversion of the head of the tibia is similar to that of the Bush bone.

The proximal half of the shaft bears a deep hollow on its lateral face. This is more pronounced than is usual in the Bush tibia, but resembling the Boskopoid fragments from Kalomo described by Gear (1926). The platycnemic index is close to the average for the Bush type. There is a distinct "Squatting facet" at the lower end of the bone.

Proportions and Stature.—The tibio-femoral index is of the same order as that of the Bush race and indicates that the distal segment of the limb is relatively long compared with the proximal. The humero-femoral index is much higher than in the Bush race, approximating to the value found in the European. This suggests that in the Doonside skeleton the upper limb was not so short in comparison with the lower as is usual in the Bush type.

The stature is estimated at about 1450 mm. This is slightly below the stature obtained for Bush females.

All the bones of the Doonside skeleton show an admixture of Boskop and Bush features with a marked preponderance of the former. This is especially seen in the skull. When tracings of B.Za.2, the skull of an accepted female Boskop type, and of the female Doonside skull are compared the marked similarity of the facial and vertical regions is very striking (fig. 4).

The outstanding difference between the two skulls, which have so many features in common, is in the length. The Doonside skull has Boskop breadth and height but Bush length. It is this combination of Bush length and Boskop breadth which makes it brachycephalic. As such it may be a further evidence of the hybridisation of the intrusive Bush stock with the indigenous Boskop stock.

Plate XX shows the Doonside skull along with the Cape Seal skull from the McGregor Memorial Collection, Kimberley. It is a skull from the Cape Colony coast which Shrubsall has designated "Strandloper"—a term which may now be defined as "Bush-Boskop hybrid." When the two skulls are compared they are markedly alike. The "Strandloper" type—that is, Bush-Boskop hybrid—was therefore not confined to the Cape Colony coast, but extended up to the Natal coast and, as previous observers in this department have shown, was even widely spread over inland South Africa.

(e) *The Country Club (Durban) Skull.*—This specimen (Durban Museum, No. 3727) is stated to have been found at a depth of 20 feet, in the sand-dunes near the Durban Country Club. No objects were associated with it. The skull is very incomplete, considerably distorted, and partially mineralised.

The remains of the skull comprise portions of the frontal parietal and temporal bones. These are very slender, the average thickness of the vault being 5–6 mm. From the fact that all the sutures of the vault are very

patent and that the bone is very thin, it appears that this is at the most the skull of a young adult, but could be that of a male juvenile adolescent, or a somewhat older female.

The skull appears to have been moderately dolichocephalic, hypsicephalic and hypsi-ovoid in cranial contour, all of them Bantu features.

The cranial capacity is estimated as 1300–1350 c.c. It is thus microcephalic, but is greater than the average found in this department for Bush skulls. The average capacity of adult Bantu skulls is, however, still greater. If, however, this skull is that of a young adolescent male or of an adolescent female, as it may be, then the cranial capacity would come into the range of Bantu cranial capacities.

In its form this skull resembles the Bantu rather than either the Bush or Boskop type. In the details of its anatomy, however, it reveals many Bush or Bush-Boskop traits. The more notable of these are the post-coronal depressions, the interparietal groove, the inferior frontal eminence, the supra-asterionic depressions, and the form of the mastoid process. It thus appears that this individual is to be regarded as of mixed Bantu and Bush-Boskopoid ancestry. In this it agrees with the Tinley Manor skeletons.

(f) *The Umgababa Fragments.*—This specimen was obtained from a wind-eroded midden deposit at Umgababa, a few miles south of Karridene. It was associated with pottery typical of the post-Smithfield period. Fragments of most of the bones were obtained. The remains are not appreciably mineralised.

Of the skull only fragments of the upper and lower jaws were obtained. The most important is a portion of the mandibular symphysis. This is deep and indicates the presence of a strong mental protuberance together with marked alveolar prognathism, a combination typical of the Bantu mandible (Shaw, 1931). The characters of the teeth are those usual in the Bantu.

The fragments of the remainder of the skeleton indicate that the individual was of larger size than is typical of the Bush race. They do not for the most part permit of exact anthropometric study. Two bones of the foot, the left navicular and right second metatarsal, are sufficiently preserved for a more detailed study. Both appreciably exceed in their dimensions the average for the Bush type, though they fall somewhat below the average for the Bantu. In their proportions these bones conform definitely to the Bantu type and are closely distinguishable from Bush specimens (Wells, 1931).

The characters which can be determined from these fragments are all essentially Bantu. They suggest that this individual was of a more purely Bantu type than the Tinley Manor skeletons.

3. Discussion.

The available skeletal material from the Natal coast consists of the group of skeletons just described, the Tinley Manor material, the Karridene skull, and the Isipofu fragments. All this material can be placed in one of three groups depending on the associated cultures—Iron Age, Stone Age, or unknown horizon.

Table I shows their distribution according to their horizons and also gives their racial type.

Table I.

	Skeleton.	Type.	Horizon.
Group A	Tinley Manor (adult)	Bantu Bush-Boskop	Iron Age.
	Tinley Manor (juvenile)	Bush Boskopoid Bantu	
	St. Lucia	Bantu Bush	
	Umhloti	Bantu Bush? Boskopoid	
	Umgababa	Bantu	
	Illovo	Boskopoid-Bush	
Group B	Karridene	Bush-Boskop	Late Stone Age.
	Isipofu	Boskopoid	
Group C	Country Club	Bantu Bush-Boskop	Unknown.
	Doonside	Boskopoid-Bush	

Group A represents a series of individuals with a mixture of Bantu-Bush-Boskop features, the remains of whom were found associated with a pottery characteristic of the post-Smithfield Iron Age and are therefore contemporary.

Group B consists of the Karridene skull and the Isipofu fragments. They represent a Bush-Boskop Late Stone Age population which seems to have had a preponderance of Boskopoid features, with no Bantu features. Group C consists of two skulls from unknown horizons. The Country Club skull with its Bantu features must belong to a population later than that represented by Group B—that is, it belongs to the Group A Iron Age type. Had any cultural objects been found with it they would probably have had the same Bantu facies as the cultural objects of the first group. The Doonside skull had the same degree of fossilisation as the Karridene skull did. It was found in the same type of reddish sandy matrix and shows the same physical features. It belongs, then, to the same Late Stone Age horizon as the Karridene skull.

These findings confirm the conclusions Wells arrived at in his discussion

of the Tinley Manor material. The pre-Bantu inhabitants of the Natal coast were a race of Bush-Boskop hybrids, similar to the people of the same epoch on other parts of the east and south coasts of South Africa, a type as yet only sporadically found in the hinterland. The southern periphery of the Bush invasion from the North mingled and hybridised with the remnants of the Boskop people driven to the coast. This Bush-Boskop hybridised type became the indigenous population.

The indigenous Bush type with its frequently recurring Boskopoid features survived alongside and imprinted its features on the Bantu, who settled in this area as a result of the first wave of the Bantu migration which brought with it a characteristic Bantu pottery. This pottery is of a type associated with Bantu iron-work. Along with the evidence of the iron ring associated with the Tinley Manor skull, this is the earliest evidence of iron-work on the Natal coast.

After the coming of the Bantu the type persisted and implanted its physical features on the invading Bantu. The predominantly Boskopoid Illovo skull with its absence of Bantu features shows that the type persisted here and there in its pure state after the arrival of the Bantu and the taking over of some of his culture by the pre-Bantu stock.

It is noteworthy that the few remains from this horizon are so preponderantly Boskopoid in type. It demonstrates that the Boskopoid influence on the pre-Bantu peoples of South Africa was just as strong in the Natal population as in the Late Stone Age Cape Coastal people.

4. Conclusions.

1. A series of skulls from Natal coastal sites have been examined. They fall into two groups—one with associated cultural objects, the other without. The first group shows a mixture of Bush, Bantu, and Boskop features, while the other group, which is older, only shows Bush-Boskop features with a slight preponderance of Boskop.

2. These skulls reveal that the pre-Bantu Natal coast population was Bush-Boskop in type and that the Boskop influence on South Africa's pre-Bantu people was equally strong in Natal as in the Late Stone Age Cape Coastal people.

3. The Bantu presumably brought iron-working to the Natal coast. In the hybridisation which took place between the Bantu and the Indigenes, the latter definitely implanted its features on the Bantu.

5. Acknowledgments.

I wish to thank all those, already mentioned in the paper, who so courteously placed their material at my disposal. I am grateful to Pro-

fessor Raymond A. Dart for his customary help and criticism, and to Mr. L. H. Wells who placed unstintedly his knowledge and statistical material at my disposal, and who has checked every step of this investigation.

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Table II.

Cranial Measurements.

	Length.	Breadth.	Height.	Least Frontal.	Bi-orbit.	Interorbit.	Bi-zygomatic.	Facial height.	Orbital height.	Orbital width.	Nasal height.	Nasal width.	Maxillo alv. length.	Maxillo alv. breadth.	Pal. length.	Pal. breadth.	Cranial capacity.
St. Lucia .	17·3	12·6	11·5	10·3	10·9	2·4	11·3	5·3	3·6	4·2	4·1	3·0	..	..	..	..	1200–1250
Umhloti .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Illovo .	..	..	..	10·0	10·7	2·6	12·6	6·1	3·0	3·9	4·4	2·8	5·4	6·0	4·6	3·8	..
Doonside .	18·1	14·4	12·3	10·1	10·9	2·1	6·4	5·6	2·9	4·0	4·4	2·6	..	..	..	..	1487
Country Club	17·5	13·7	11·7	9·3	9·9	..	..	..	..	..	..	..	..	..	..	..	1315
Umgababa	..	..	..	..	..	..	..	..	..	.?	..	..	..	..	..	..	..

TABLE III.

Mandibular Measurements.

	Ramus.		Body.		Symphyseal Height.
	Height.	Width.	Height.	Width.	
St. Lucia . .	4·5	3·3	2·5	1·7	2·6
Umhloti . .	..	..	1·8	1·3	2·3
Illovo . .	5·4	3·7	2·5	1·6	3·1
Doonside . .	..	..	2·7	1·5	3·3
Country Club .	..	..	..	..	..
Umgababa .	..	..	..	..	3·3

TABLE IV.

Indices.

	Skull.									Mandible.	
	Cephalic.	Altitudinal.	Fronto-parietal.	Inter-orbital.	Facial.	Orbital.	Nasal.	Maxillo-alveolar.	Palatal.	Body.	Ramus.
St. Lucia .	73	66·6	76·0	22·0	47·0	85·7	73·2	..	..	68·1	73·3
Umhloti .	..	..	..	..	..	..	..	..	..	72·2	..
Illovo .	..	..	..	24·3	48·4	77·0	63·6	111·1	82·6	64·0	68·5
Doonside .	79·5	68·0	70·1	19·2	37·8	72·5	59·2	..	..	55·6	..
Country Club	78·6	67·0	68·0	..	..	..	..	..	..	..	..
Umgababa	..	..	..	..	..	..	..	..	..	..	..

TABLE V.

Measurements of Doonside Femora.

	Length.	Circumference.	Index of head.	Index of neck.	Platymeric index.	Pilastine index.	Circum. epicond. index.	Angle of torsion.	Angle of neck.	Height of curvature.	Length curve index.	Length circum. index.	Estimated stature.
Right	..	7·68	95·3	62·5	91·7	117·9	83·3	28·5	125·5	2·75	..	..	1410 mm.
Left	36·6	7·7	96·05	64·7	80·9	111·3	87·2	30·0	127·5	2·7	7·4	18·3	

TABLE VI.

Measurements of Doonside Tibia.

	Maximum length.	Circumference.	Dorso-vent. diameter of shaft.	Medio-lat. diameter of shaft.	Length circum. index.	Platymeric index.	Angle of torsion.	Angle of retroversion.	Estimated stature.
Left	31·1	7·25	3·02	2·1	23·3	69·5	16°	12·5°	1490

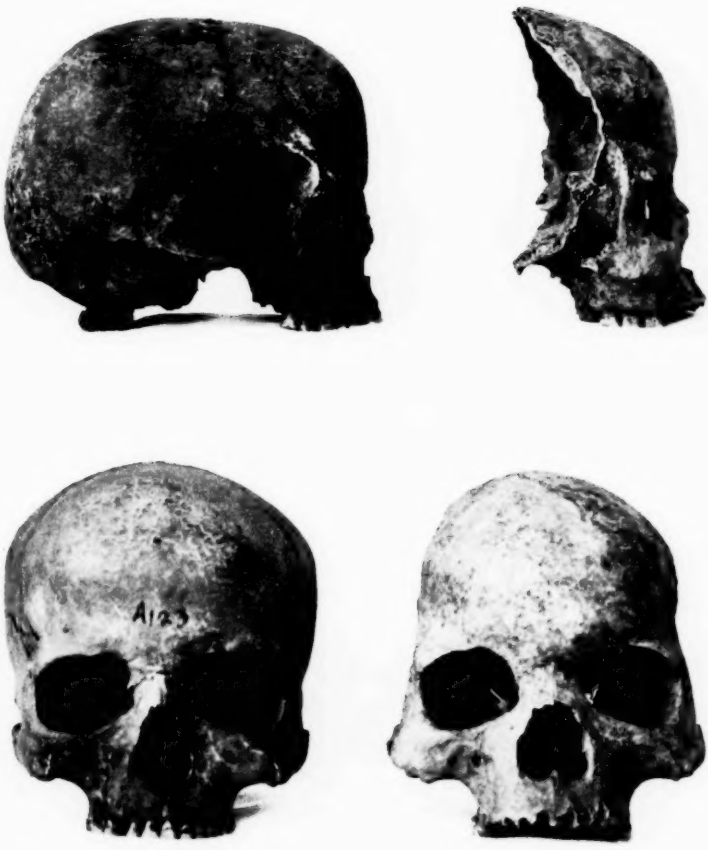
TABLE VII.

Humeral Measurements.

	Length.	Circumference.	Dorso-ventral diam. shaft.	Medio-lat. diam. shaft.	Cranio-caud. diam. head.	Ant.-post. diam. head.	Calibre index.	Shaft index.	Head index.	Estimated stature.
Illovo .	26·7	5·6	1·7	1·8	3·8	3·6	21·0	94·4	94·7	1429
Doonside	26·9	5·5	1·7	1·8	3·6	3·6	20·5	94·4	100·0	1441

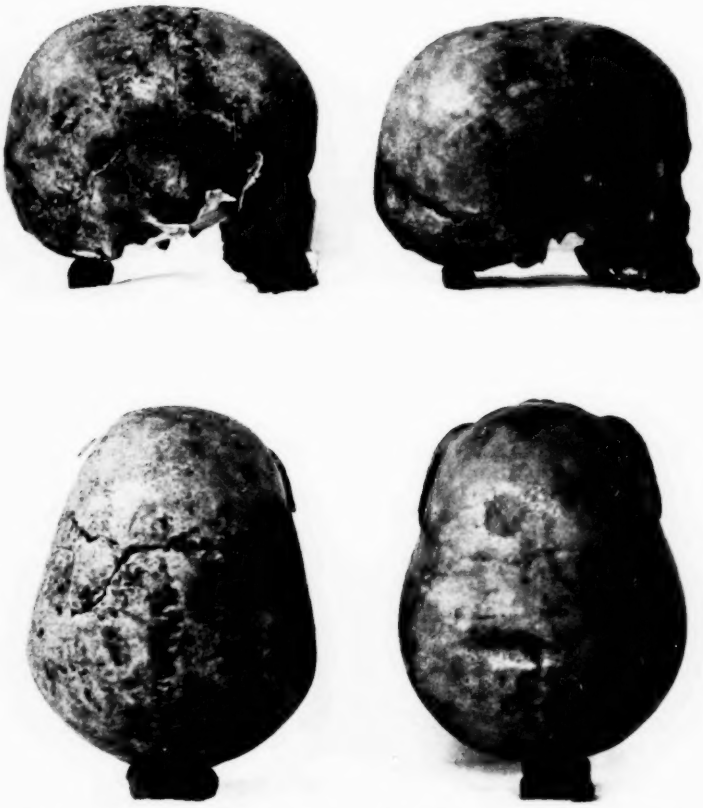
The St. Lucia skull (right) and a typical Bantu skull (norma verticalis).

Alexander Galloway. *Neill & Co., Ltd.*



The Illovo skull with skull A123, a typical Bush skull, norma lateralis (above) and norma facialis (below).

Alexander Galloway. *Neill & Co., Ltd.*



The Doonside skull, with the "Strandloper" skull from Cape Seal (M.M.K. 128), norma lateralis (above) and norma verticalis (below).

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NOTE ON THE STEM STRUCTURE OF *BOSCIA REHMANNIANA*, PEST.

By R. S. Adamson.

(Read June 19, 1935.)

In a communication read before the Society recently Dr. Galpin described some of the features of the distribution and behaviour of *Boscia rehmanniana*, including the remarkable way in which branches separate by splitting down portions of the trunk and continuing growth. This suggested that an investigation of the structure of the stem would be of interest. The present investigation has been carried out with this object, on material collected by Dr. Galpin at Naboomspruit, for which I desire to express my thanks.

It was at once apparent that the old stems of the tree have anomalous secondary growth of an unusual kind. The earlier stages of growth are normal; stems up to as much as 5–7 cm. in diameter have no trace of the irregularities that are obvious in the old ones. The younger stems have a smooth bark, with superficial cork formation, and a relatively broad cortical zone. The wood is hard and moderately heavy : about 45 lb. per cubic foot (8·6 gram per c.c.). The wood is largely composed of fibres which are narrow, thick-walled, and, though not very long, not regularly parallel to one another. Vessels occur in the wood in radial groups of 4–6, most often in a single row. The vessels are pitted and are composed of short segments which have a single round terminal pore. Rings occur in the wood but are not distinct or at all regular. They are marked by terminal parenchyma which forms almost complete zones. Rays are numerous, one cell across, and most commonly 2–8 cells deep, though there are occasional ones 12–16 cells in depth. The phloem zone contains large numbers of fibres which in the older parts constitute a much larger proportion of the tissue than the conducting cells. The rays in the phloem are widened by the stretching of the cells.

In larger stems a gummy degeneration of the wood parenchyma may occur. This may involve the layers adjacent to the parenchyma itself and finally produce a split.

Old stems have a very irregular and deeply fluted surface. They

generally become hollow owing to rotting of the centre. The hollow centre has also a lobed irregular outline.

The plan of construction of the stem is that of a succession of zones of xylem and phloem, but these are not regularly concentric nor continuous round the axis. They are quite evidently not produced by a cambium carrying on a regular series of divisions. The xylem in each zone is not homogeneous: through it lines of tissue run in a rather irregular way and from these the rays spread, both outwards, also inwards, and to a less extent in other directions (fig. 1).

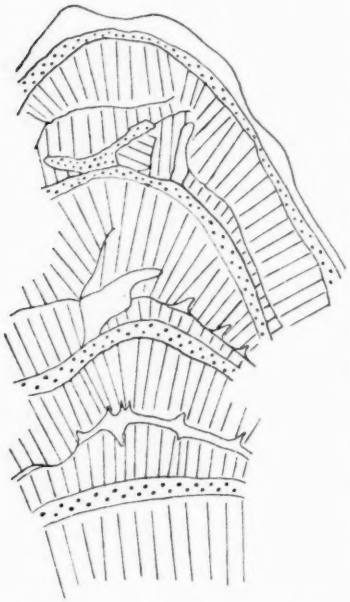

FIG. 1.—Tracing from outer part of a large stem in cross-section illustrating the arrangement of successive zones. × $\frac{2}{3}$. Xylem indicated by lines, phloem by dots, ground tissue plain.

The construction is best followed by tracing the beginnings of these zones. When a new secondary cambium is formed it arises external to the previously formed phloem and at a variable distance from it. The new cambium is not at first a continuous ring but starts as a number of separate portions not usually at a uniform distance from the phloem zone. The portions become joined up later. When a part arises immediately outside the phloem zone its development is normal. Much more commonly, however, the portions arise some distance further out, and from them development proceeds from two active zones which produce new tissues in opposite directions—one centrifugally in the ordinary way, the other centripetally with the tissues with an inverse orientation. The active zones may commence as adjacent layers or be separated by two or more layers of ground-tissue cells (fig. 2).

The centripetal development does not continue for long owing to pressure. When growth ceases the inwardly growing cambia are represented by only one or two rows of undifferentiated cells, whereas those with the ordinary centrifugal growth remain as zones of 10–15 layers of thin-walled cells. Annual rings are formed in both the centrifugal and centripetal zones.

This type of growth results in a considerable degree of complication,

especially in the inner parts of each successive zone on account of the separate origin of the parts of the cambium and the varying amount of centripetal growth (fig. 3). The irregular lines visible in the wood, most commonly a short distance outside the previous zone of phloem, mark the positions where the cambia started. The junction line in the phloem

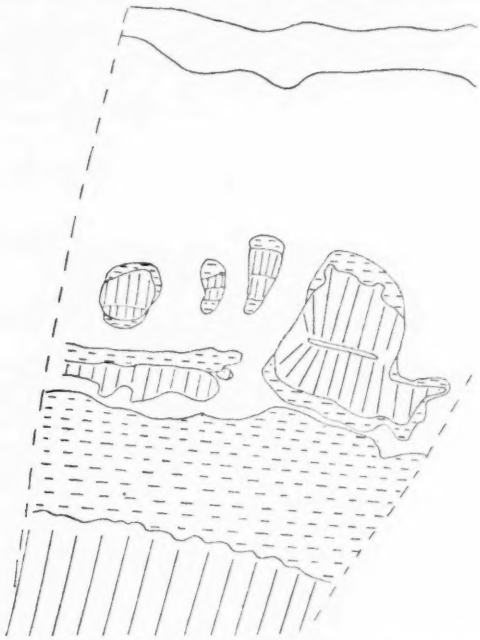

FIG. 2.—Outline of a transverse section of the outer part showing commencement of new growth. × 10.

Xylem, lines; phloem, dashes.

between that part formed centripetally and the older part is also discernible but less obvious.

In the detailed structure the tissues formed from these secondary cambia are the same as those of younger stems, except that many of the rays are two to three cells across. There are also occasional broad compound rays. The rays do not run continuously through the whole of the secondary tissues : a separate system of rays is present in each portion formed by a cambium. Connection between one part and adjacent ones, outside or inside, is afforded by the ground tissue. Such ground tissue is found adjacent to the starting-points of the cambia, and also as broad but

not continuous bands, looking much like very broad rays, between those portions of tissue that arise from separate segments of cambium. Broad bands of ground tissue also occur in association with branch traces.

The arrangement of the rays and ground tissue, together with the rather irregular course of the fibres, renders the wood incapable of being

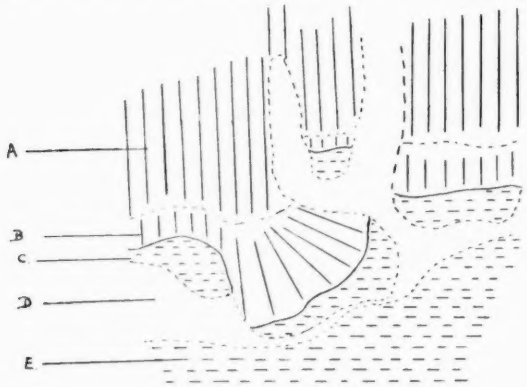

FIG. 3.—Transverse section at junction of zones. × 10.

Shading as in fig. 2. A, centrifugally formed xylem; B, centripetally formed xylem; C, centripetally formed phloem; D, ground tissue; E, phloem of previously formed zone.

split longitudinally along definite planes. When split the surface is irregular and often rather undulating.

In the trunk the cambia that are no longer active undergo gummy degeneration and form lines of splitting. The very irregular outline of the central hollow results from such splitting combined with the rotting of the inner parts.

The construction of the stem affords an explanation of the way in which growth continues after the splitting down with a branch. Separation takes place along an old cambium line, but the detached part has an active, or potentially active, cambium both outside and inside, and consequently is readily able to carry on independent growth.

Anomalous secondary growth, with the formation of successive secondary extrafascicular cambia, has been described previously for some members of the Capparidaceae, though not for the genus *Boscia* (*cf.* de Bary, Pax, Pfeiffer, Solereder). In none of the cases described, however, is there the complication that occurs in this tree. The cambia formed develop secondary tissues centrifugally. There is no sign of the centripetal growth, with the tissues produced with the inverse orientation, in the inner part of each zone.

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THE GENUS *TRIPTERODON* PLAYFAIR.

By J. L. B. Smith.

(With Plates XXI–XXIII and one Text-figure.)

(Read June 19, 1935.)

The genus *Tripterodon* Plyfr. with the single African species *orbis* Plyfr. has hitherto not received more than brief attention, and the features which would indicate its taxonomic relationships do not appear to have been investigated in any detail.

A careful examination of the skeletal and structural features of this genus has led to a comparison with the same features in the obviously related genera *Platax* Cuv. and *Drepane* Cuv.; with these is allied *Ephippus* Cuv. It has not been possible to obtain a specimen of the latter for dissection, but it is obvious from accounts dealing with the internal structure, as well as from the external features in a specimen examined, that this genus and the three others mentioned form a natural group.

Although *Platax*, *Ephippus*, and *Drepane* are among the earliest described genera of fishes, there is some diversity of opinion among systematists as to their taxonomic relationships. Regan (Ann. Mag. Nat. Hist., 1913 (8), vol. xii, p. 127), who based his opinions chiefly upon skeletal features, placed *Platax* with *Ephippus* in the **Ephippidae**, and separated *Drepane* as the type of the family **Drepanidae**; in this latter case he has not given any detailed reasons for his conclusion beyond that *Drepane* has no subocular shelf, while stating that in all other skeletal features the two families are identical. *Platax*, with a feeble subocular shelf, in this respect falls midway between *Drepane* and *Ephippus*, the latter having a strong shelf.

Barnard (Ann. S.A. Mus., 1927, vol. xxi, pp. 600 and 605) followed Regan's classification.

Fowler (Proc. Ac. Nat. Sci. Phil., 1925, vol. lxxvii, p. 251) at first accepted Regan's classification for *Drepane*, but has more recently (Bull. U.S. Nat. Mus., 1929, vol. viii, p. 25; and Proc. Ac. Nat. Sci. Phil., 1934, vol. lxxxvi, p. 479) accorded *Drepane* only sub-family rank in the **Ephippidae**, while separating *Platax* as a monotypic family. In the absence of more precise reasons, based on skeletal data, for the recognition of the **Drepanidae**

by Regan, Fowler's later classification, although obviously based on external features only, might appear almost justifiable.

The genus *Tripterodon* Plyfr. has been somewhat arbitrarily placed in various families. Fowler (Proc. Ac. Nat. Sci. Phil., 1925, vol. lxxvii, p. 242; and Bull. U.S. Nat. Mus., 1933, vol. xii, p. 202) placed *Tripterodon* in the **Girellidae,** whereas more recently (Proc. Ac. Nat. Sci. Phil., 1934, vol. lxxxvi, p. 478) he has described the single species of that genus as a *Chaetodipterus* Lac., placed with *Drepane* in the **Ephippidae,** and has thus indirectly recognised that *Tripterodon* is closely related to *Ephippus* and to *Drepane*. Barnard (*loc. cit.*, p. 725) placed *Tripterodon* in the **Sparidae,** and also confused *Tripterodon* with *Chaetodipterus* (*loc. cit.*, pp. 603, 604) by accepting what have proved to be somewhat excusable malidentifications by earlier workers on South African fishes.

Examination has shown that the inclusion of *Tripterodon* in the **Girellidae** has little to recommend it. Fowler has probably regarded the dentition as a feature of paramount significance, but there is little else in common and so much divergence in important features that this diagnosis cannot be accepted.

In the majority of skeletal features which systematists have hitherto regarded as of chief significance, the four genera *Platax*, *Ephippus*, *Tripterodon*, and *Drepane* are so closely allied that they might easily be regarded as all falling within one family. Nevertheless *Drepane* is distinguished by several features, notably the structure of the upper jaw, which, although apparently not regarded as important by earlier workers, would appear to justify separation from the remaining three genera by full family rank. According to the degree of taxonomic significance assigned to these special characteristics of *Drepane* it is not even unlikely that the **Drepanidae** may ultimately be raised to the rank of a division, with probable inclusion of the **Chaetodontidae.**

With regard to the classification of the remaining three genera there are several alternatives, but the selection of any one of these will very largely depend upon the personal interpretation of the taxonomic significance of the relatively few features in which these genera differ one from the other. They may be regarded as each forming the type of a separate family, although the separation of *Platax* from the remaining two, as proposed by Fowler (*loc. cit.*), merely upon the somewhat abnormal external features of that genus, does not appear to be justified, and is not accepted here. Should, however, this distinction for *Platax* otherwise meet with general approval, *Tripterodon* would then appear to have at least equal claims to recognition as the type of a separate family. It may here be indicated that Fowler's key to the genera of the **Ephippidae** (Bull. U.S. Nat. Mus., 1929, vol. viii, p. 24) does not agree with his diagnosis of the family.

The strong subocular shelf and the setiform dentition are distinctive characters which might reasonably be regarded as justifying full family rank for *Ephippus* as opposed to the closely related *Platax* and *Tripterodon*. Nevertheless, when all the available evidence is carefully weighed, it appears to be more in keeping with generally accepted limits to adopt the classification here proposed, *i.e.* in view of the general agreement in the majority of important features, the genera *Platax*, *Ephippus*, and *Tripterodon* be placed in a single family, the **Platacidae.*** The special features of *Ephippus* are then assigned only sub-family rank, while *Platax* and *Tripterodon* are placed together in the sub-family **Platacinae,** as arranged below in the key to the genera of the family **Platacidae.**

The following summary indicates the main features in which the **Drepanidae** may be regarded as well distinguished from the **Platacidae.**

I. Anterior maxillary processes produced, meeting beneath the anterior margin of the mesethmoid, over the premaxillary pedicels. Premaxillaries slender, highly expanded distally above and below. Premaxillary pedicels very long, oblique, entering the skull beneath the olfactory sacs, sliding in a deep excavation extending between the lower orbital margins. Posterior ribs extensively articulated with the parapophyses. Gill-membranes narrowly fused with isthmus. Pectorals much longer than head. Scales cycloid. (Caudal more or less rounded) . . . . . **Drepanidae.**

II. Maxillaries normal, not meeting anteriorly over the premaxillary pedicels. Premaxillaries not or scarcely expanded distally. Premaxillary pedicels not penetrating the skull, entirely anterior to the orbital margins, sub-vertical. Posterior ribs not or scarcely articulated with the parapophyses. Gill-membranes broadly fused with isthmus. Pectorals shorter than head. Scales ctenoid. (Caudal truncate or nearly so) . . . . . **Platacidae.**

In most other respects the families agree.

The curious shape and disposition of the premaxillaries of the **Drepanidae** reveal the connection between that family and the **Chaetodontidae.** In the latter, although the premaxillary pedicels are fairly short, they are very oblique, and penetrate below the olfactory sacs. In *Chaetodon setifer* Blch. there does not appear to be the extensive articulation of the ribs with the parapophyses indicated by Regan (*loc. cit.*) as characteristic of the family.

It has earlier been indicated (Smith, Proc. Roy. Soc. S.A., 1935, vol. xxiii, p. 267) that the genus *Dichistius* Gill. reveals affinities with the **Platacidae,** and connects that family with the natural group of the **Scorpididae** and the **Kyphosidae.**

* *Platax* (Cuv. Reg. Anim., 1817, vol. ii, p. 334) has page preference over *Ephippus* (*ibid.*, p. 335), and should therefore determine the name of the family.

Family PLATACIDAE.

Body compressed, elevated or ovate. Front profile steep. Mouth terminal, small, moderately or scarcely protractile, more or less horizontal. Maxillary moderate, without anterior forward expansion. Premaxillary pedicels fairly long. Jaws with bands of movable teeth, slender and setiform, or compressed and notched. Palate edentate, vomer sometimes feebly dentate. Preopercle not, finely, or coarsely, serrate (spinate in young?). Gill-membranes united, broadly fused with isthmus, openings lateral. Gill-rakers short, few. Branchiostegals 6 (or 7?).

Dorsal long, of a few spines, soft dorsal longer than spinous. Soft fin scaly. Below the skin a stout antrorse procumbent spine, fused with the basipterygial of the first two exposed spines; anterior to this, three obsolescent antrorse spines, the anterior (inferior) overlapping the supraoccipital apex (Pl. XXII).

Anal of three spines, with small antrorse recumbent spine on anterior basipterygial; soft fin scaly. Pectorals short. Ventrals fairly or very long, with axillary process. Caudal of 17 principal rays, of more or less truncated form. Scales ctenoid, small or moderate. Lateral line gently curved.

Vertebrae 24 (10 + 14), with parapophyses from the 4th. Anterior ribs expanded proximally. An elevated occipital crest, anterior margin expanded. No parietal crests. Subocular shelf feeble or strong. Air-bladder posteriorly bifurcated into two caudal prolongations (Pl. XXIII).

The three genera here mentioned occur in the Indo-Pacific.

Key to the Genera.

I. **Ephippinae.**—Subocular shelf strong. Teeth setiform. (Scales fairly large) . . . . . *Ephippus.*

II. **Platacinae.**—Subocular shelf very feeble. Teeth compressed, tricuspid. (Scales moderate or small.)

A. Dorsal spines graduated, none longer than longest soft rays. More than 50 series of scales. Preorbital not very deep. Premaxillary pedicels shorter than rami . . . . *Platax.*

B. 3rd–5th dorsal spines elongate, longest longer than posterior spines and than longest soft rays. Less than 50 series of scales. Preorbital very deep. Premaxillary pedicels as long as rami . . . . . *Tripterodon.*

Genus Ephippus Cuv.

I have seen only a single specimen of the species *orbis* Bloch, from India. This has not yet been found in the South African region, but will probably be discovered there with more intensive collecting. It occurs in the Indian region, but appears to be nowhere very plentiful.

In external form, chiefly in the shape of the fins, this species resembles *Tripterodon orbis* Plyfr. closely, but has a shallower preorbital and the body is more uniformly orbicular, while the setiform teeth are immediately diagnostic. As is shown below, the species *goreensis* C. and V. from the West Coast of Africa shows even more remarkable resemblance to *T. orbis* in external form.

Genus PLATAX Cuv.

Premaxillary pedicels short, almost vertical. Supraoccipital and anterior dorsal basipterygial becoming greatly enlarged with age. Preopercle margin entire in adult. Sometimes a few fine teeth on vomer. Teeth rather slender, but apically somewhat dilated and sharply tricuspid.

On casual examination the teeth appear setiform. The dentition in this genus is intermediate in form between that of *Ephippus* and that of *Tripterodon*.

Fowler (Bull. U.S. Nat. Mus., 1929, vol. viii, p. 17) has stated that the air-bladder is simple. In those specimens I have examined the air-bladder has a median longitudinal septum, and is bifurcated into two caudal extensions, which are more pronounced in large specimens.

There appear to be fairly extensive growth changes and many nominal species have been proposed, but the majority of recent workers appear to accept only two, *pinnatus* Linn. (*teira* Cuv.=) and *orbicularis* Bloch (*vespertilio* Cuv.=). Diagnoses of these species do not always agree, and there appears to be some confusion with regard to the features upon which differentiation is based.

As far as South African material is concerned, positive identification with either species, *i.e.* if both are recognised, is difficult.

It would appear not unlikely that there is but a single rather polymorphous species, though I have not sufficient material to enable me to decide this.

Genus TRIPTERODON Plyfr.

1866. Playfair, Fishes of Zanzibar, p. 42.
1927. Barnard, *loc. cit.*, p. 725.
1933. Fowler, Bull. U.S. Nat. Mus., vol. xii, p. 202.

Premaxillary pedicels as long as rami, but not reaching frontals, almost vertical; superior lateral processes very small. Maxillaries normal, short and deep, moderately expanded distally. Subocular shelf extremely feeble, merely a slight pointed downward expansion of the second suborbital.

Vertebrae 24 (10+14), first very much reduced, not ankylosed with the skull. Parapophyses from the fourth precaudal. Ribs all sessile. Epipleurals extremely fine, hair-like. Haemal spines of anterior caudal vertebrae with median longitudinal expansion below the extensions of the air-bladder (Pls. XXII and XXIII). Post-temporal forked, not ankylosed. Post-clavicle long and slender. Pectoral radials 5, upper three bobbin-shaped, only the lowest (5th) abutting on the coracoid (fig. 1).

Branchiostegals 6. Pseudobranchiae absent (concealed). Teeth very compressed, slightly recurved, tricuspid. Pyloric caeca few (3–4).

Other characters as outlined for the family.

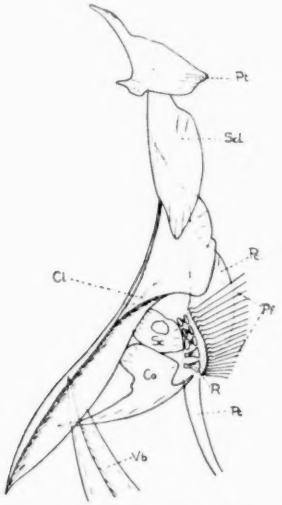
At present only a single species, *orbis* Plyfr., is known from the east coast of Africa.

Tripterodon orbis Plyfr.

(Pls. XXI–XXIII)

Tripterodon orbis Plyfr., Playfair, *loc. cit.*, p. 42, pl. vii, fig. 1. Fowler, Proc. Ac. Nat. Sci. Phil., 1925, vol. lxxvii, p. 242; and 1933, *loc. cit.*, p. 202. Smith, Rec. Albany Mus., 1935, vol. iv, p. 209.*

Chaetodipterus orbis (non Bloch), Norman, Ann. Mag. Nat. Hist., 1922 (9), vol. ix, p. 321 (record only, error in Brit. Mus. Register).†



TEXT-FIG. 1.—Left pectoral girdle of *Tripterodon orbis* Plyfr. showing orientation of ventral basipterygium.

Cl., cleithrum; *Co.*, coracoid; *Pc.*, post-clavicle; *Pf.*, pectoral fin; *Pt.*, post-temporal; *R.*, radial; *Sc.*, scapula; *Scl.*, supracleithrum; *Vb.*, ventral basipterygium.

Chaetodipterus goreensis (non C. and V.), Barnard, *loc. cit.*, p. 603. Fowler, Proc. Ac. Nat. Sci. Phil., 1934, vol. lxxxvi, p. 478, fig. 43.

Body more or less orbicular, more angular in adults, fairly compressed. Dorsal profile very elevated, slightly undulate, with moderate interorbital prominence, which increases with age.

Depth 1·2–1·4, length of head 3·0–3·2 in length of body. Eye 2·7–3·7 (Ad.), snout 1·6 (Ad)–1·8, interorbital 2·7–3·2 and postorbital 3·5–4·0 in length of head. Least depth of preorbital 1·0 (Juv.)–1·4 times eye.

Nostrils wide apart, anterior rounded, posterior long and oval. Mouth horizontal, small, terminal, only slightly protractile. Maxilla extends to below anterior nostril.

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* In this paper *Chaetodipterus orbis* Bloch, recorded by Barnard, *loc. cit.*, p. 604, has erroneously been included in the synonymy of *T. orbis*; actually this author had merely accepted the British Museum record.

† Private communication from Mr. J. R. Norman.

Lips thick, especially upper, which is ½ eye deep at snout tip. All the teeth movable compressed tricuspid incisiform, in about 4 rows, the outer of 18–20 teeth in each jaw: the inner teeth embedded in fleshy pads.

Palate and tongue edentate. Gill-membranes broadly fused with isthmus. Gill-rakers 9–10, short, about 4–5 in gill-filaments, which are 1⅓–1½ in eye. Preopercle serrations more marked in juveniles.

D IX, 19–21, originates above hind margin of opercle. First spine very short; second twice the first; third 1·5–2·2 (Juv.); fourth 1·3–2·0 (Juv.); fifth 1·0–1·2 times head; remainder short, about equal to eye. Soft rays abruptly longer than last spine, 6th–8th longest, 1·1–1·4 in head. Scaling on soft fin very dense at base. Base of spinous dorsal about as long as head, of soft dorsal 1·4–1·5 times head.

A III, 16–17, spines fairly short and stout, second longest. Anterior rays longest, 1·2–1·4 in head, edge of fin almost straight.

Pectorals rounded, 1·2–1·6 (Ad.) in head.

Ventrals 1·0–1·6 (Juv.) times head, first ray filamentous.

Caudal with hind margin gently undulate, with median convexity. Least depth of peduncle about 2·6 in head.

Scales ctenoid (Pl. XXIII), lateral line scales smaller than adjoining scales but not hidden (Pl. XXIII), l.l. 43–45, l.tr. $\frac{12\text{–}13}{23\text{–}24}$ (origin of first dorsal spine back), 7 series on cheek, not much smaller than opercular scales.

Colour: Silvery brown, with dark cross-bars of varying width, first from nape through eye to chest, second from before dorsal origin, thereafter 3 pairs alternately narrow and wide, and ninth bar indistinct on peduncle. Bars generally narrower than interspace. Snout dark. Spinous dorsal, ventral, and anterior portion of soft dorsal and anal, black. Pectorals light, dark base. Soft dorsal and anal and caudal with obscure series of dark spots.

Length.—Up to 300 mm. (Playfair).

Locality.—Durban, Delagoa Bay, Zanzibar.

Seven specimens, from 97–215 mm. in length, examined.

A very characteristic species, easily recognised by the shape of the body and fins, by the restricted gill-openings, and by the apically brown, strongly tricuspid teeth.

It is not remarkable that this species has been confused with *Chaetodipterus goreensis* C. and V. (Cuvier and Valenciennes, Hist. Nat. Poiss., 1831, vol. vii, p. 125, pl. 178), for in general external features the two species resemble one another so closely that only detailed comparison could show the difference between them.

In so far as may be judged from the description of the type of *goreensis* (an adult) the sole external difference of any significance between that species and *Tripterodon orbis* is in the dentition, the former having typical brush-like setiform teeth. Besides this the preorbital in *goreensis* does not appear to be as deep as in *orbis*, while C. and V.'s figure shows the cheek scales to be very much smaller than those on the opercle, which is not the case in *orbis*, the 3rd and 5th dorsal spines not filamentous, and the upper lip not as deep as it is in *orbis*.

A later description of *goreensis* by Pellegrin (Ann. Inst. Ocean., 1914, vol. vi, p. 55, figs. 7 and 8) does not mention the dentition, shows the preorbital to be deeper, and the 3rd–5th dorsal spines to be short in the juvenile and elongate and filamentous in the adult stage, which latter growth change appears rather exceptional.

So similar are *goreensis* and *orbis* that, had Cuvier not made the positive statement about the setiform dentition of the former, I should have had little hesitation in regarding the two as conspecific, for the remaining differences are unimportant, and the conflicting statements about the lengths of the 3rd–5th dorsal spines may probably be attributed to accidental shortening of the fragile filamentous extensions of these spines.

In so far as my specimens are concerned, the chief growth changes observable are that the preorbital becomes markedly deeper, the interorbital convexity greater, the 3rd–5th dorsal spines shorter, and the ventrals shorter with increase in size of the fish. In juveniles the ventrals reach well along the base of the soft anal, in adults barely beyond the origin of the spinous fin. I have not seen any very young specimens.

A re-examination of the type of *goreensis* might be of interest.

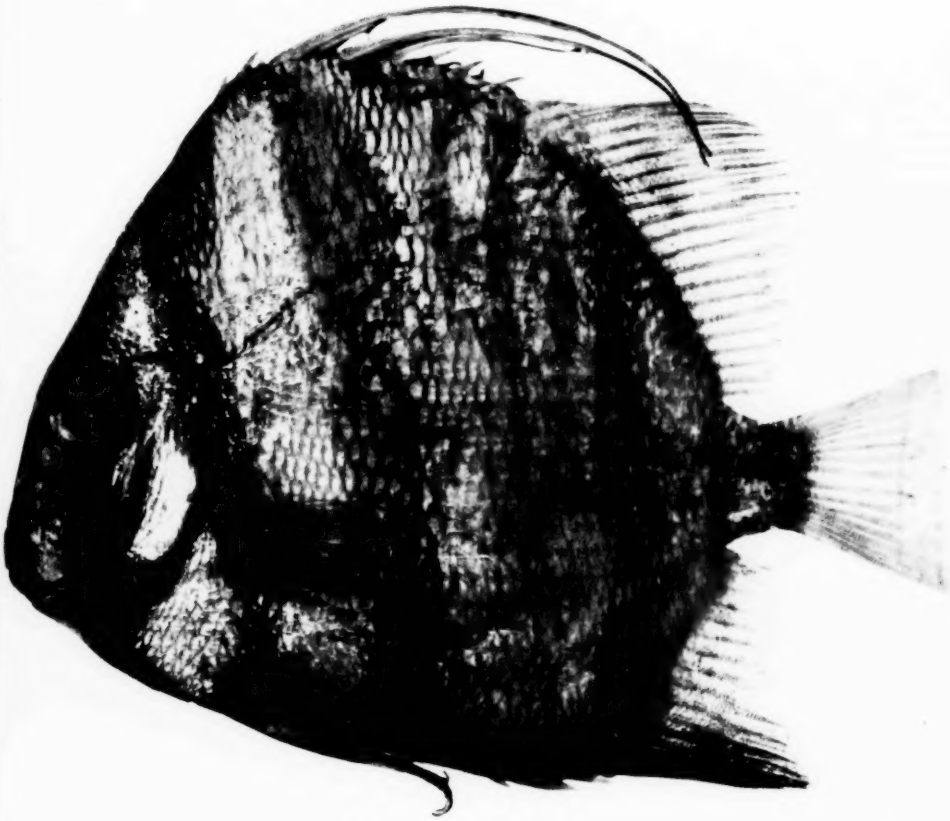
Fowler's specimen described as *goreensis* (*loc. cit.*) might be either that species or *orbis*, since he does not mention the nature of the dentition. There is, however, little doubt that the specimen is conspecific with *orbis* as here accepted. In the description Fowler stated that the 4th dorsal spine varies from 1·6–2·3 in length of body, whereas in the figure it is shown to be much shorter, about 3. Also the shape of the anal fin in the figure agrees neither with that shown for *goreensis* (C. and V., *loc. cit.*, and Pellegrin, *loc. cit.*) nor with that of my specimens of *orbis*.

T. orbis is only an occasional capture in the nets at Durban, and is apparently hardly ever encountered during the winter months. There appears to be no record of its occurrence any distance south of Durban. I have recently received a large collection of representative fishes from the coast of Tanganyika Territory (collected during the summer months), and since *orbis* was not among them it may be concluded that it is not abundant even in the neighbourhood of the type locality.

Nothing is known of the habits of this species, but they probably resemble those of *Platax* and *Drepane*, and it probably lives chiefly among reefs. None of the specimens I have examined have been sexually mature.

I wish to express my gratitude to Dr. Barnard, Assistant Director of the South African Museum, for the loan of material and literature. Also to the Carnegie Research Fund (through the Research Grant Board of South Africa) for generous financial assistance.

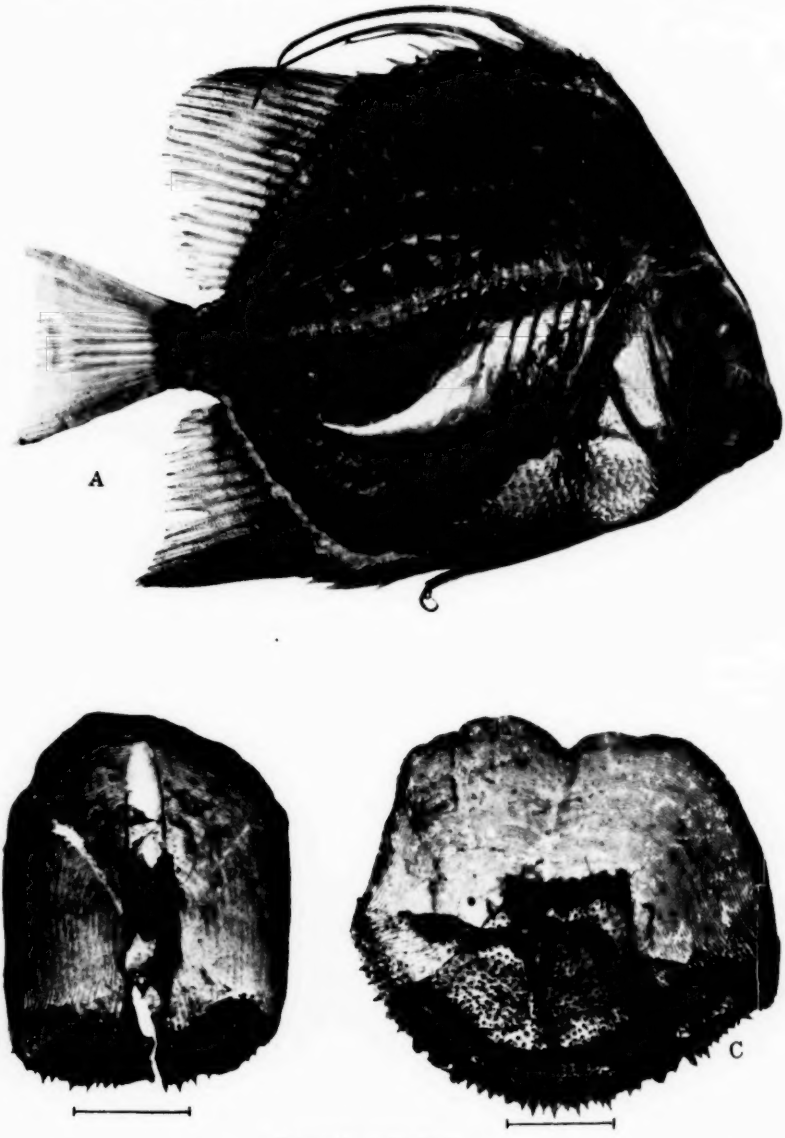
Albany Museum,
Grahamstown,
May 1935.



Tripterodon orbis Plyfr. × 1½.

Tripterodon orbis Plyfr. ×1⅓.
Stained and cleared specimen showing skeleton, with upper half of the paired structures removed.

Smith. *Neill & Co., Ltd.*



Tripterodon orbis Plyfr.

A. Showing structure of air-bladder. B. 7th lateral line scale. C. Scale above lateral line below spinous dorsal. Scales from specimen 185 mm. in length. The lines below B and C represent 1 mm.

THE NATURE OF TEMPERAMENT.

By S. Biesheuvel, M.A., Ph.D.

(Communicated by H. A. Reyburn.)

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I. Introduction.

This Temperament study is the outcome of some theoretical considerations of the Personality Problem. A brief exposition of the point of view adopted follows.

Personality study has taken two main directions: a search for distinct and unitary variables on the one hand, and the psychoanalytic, or the individual psychological approach on the other hand. The difficulties encountered are due to the great diversity of factors of which personality is the resultant.

When two individuals have the same Temperamental make-up their personalities may vary widely owing to differences in intelligence, environment, and specific experiences. Personality can thus be considered an emergent of several variables, which can occur in a large number of combinations. The attempts to classify these emergents have, however, been only partially successful. By concentrating on one aspect of behaviour, such as emotional stability and adaptation, which are important from a psychiatric point of view, personality uniformities can be detected and types can be drawn up accordingly. Such types do not discriminate between people in respect of other and equally important forms of behaviour such as social reactions, intellectual life, general motivation, to name but a few. Unless these could all be shown to be determined in some definite way by emotional stability, or by whatever other classifying criterion one happens to be using, the resulting typology could only have a psychiatric or specific, and not a universal validity.

The Cyclothyme-Schizothyme division of Kretschmer, the Introvert-Extravert Attitudes of Jung, the pansexual types of Freud are good examples of this type of classification. Jaensch (1) says of the first: "The great and lasting significance of the Kretschmer theory must in my opinion be found in the contribution it makes to the etiology of the chief classes of psychoses.

On the other hand, its meaning becomes falsified, and attention is led away from this chief point if one tries to make out of this theory a Normal Typology, which it definitely is not." The psychiatric classification of Kretschmer shows that people belonging to the pyknic constitution group display the cyclothyme behaviour pattern, which is throughout marked by an easy and adapted discharge of emotionality. In the asthenic group, possessing the schizothyme behaviour patterns, the emotional discharge is liable to be blocked and complexes are readily formed. It is important for the psychiatrist to know which people are liable to psychic clefts, and what the effect of the complex formation is. It is still more important to have a comparatively straightforward clinical test, such as constititution, to identify them by. Apart from this liability or non-liability to complex formation, there is little consistency either within the two groups or between them. Individuals in both differ or agree indiscriminately on a number of highly important personality attributes. Hence constitution is not a simple and unitary personality variable. It corresponds to a Personality Gestalt, the attributes of which Kretschmer (2) ably described, though only certain of its genetic factors emerge at all clearly. That further factors remain unanalysed follows from the significant differences, which occur within the groups. What accounts, for instance, for the various mood types ranging from the predominantly hypomanic to the predominantly depressed, which occur along the diathetic mood scale of the cyclothymes? This incompleteness is the logical consequence of Kretschmer's statement that for him Temperament is a heuristic notion, the precise nature of which has not yet been defined.

There is evidence that Introversion-Extraversion are similar Gestalt qualities, characterising the responses of otherwise different people to specific aspects of environment. Spearman (3) remarks: "Such a name as Introversion only serves in the first place to bring together an indefinitely large class of mental tendencies. It does not, pending further evidence, indicate that all the tendencies falling within this class will vary proportionally in any individual." The "further evidence," from recent researches by J. R. and R. B. Guilford (4), is to the effect that "Introversion and Extraversion in the sense of a single general dimension of personality represented in every item of the typical test is a myth." This bears out our contention that Introversion and Extraversion are possibly particular configurations of a number of variables. They occur when certain not necessarily identical temperament factors are genetically subjected to specific environmental conditions.

It is evident that no complete account of the nature of personality can be obtained from this type of classification. The complexity of interrelation is too great; they tell one something about some people, at some

given time, without clear analysis of the component factors of the Gestalten and the implication of different combinations. Hence a normal personality typology or classification of general, as distinct from specific value, is out of the question.

A different approach is therefore suggested. A distinction is drawn between that psycho-physical equipment which could be called Temperament, and its elaboration into unique emergents or personalities, under the influence of environment, experience, intelligence, and the urgency of instinctive drives such as sex. Once the nature of Temperament has thus been defined the different manifestations in the shape of combinations of fundamental variables can be related to those Personality Gestalten, which have already been shown to exist. In practice this means a typological or "factor" Temperament scheme in which the implications of each Temperament type (*i.e.* potential adjustments or maladjustments, a tendency to develop certain attitudes or complexes under specific environmental conditions) are clearly established. Having measured the Temperamental equipment of a subject by means of tests or scales the clinical psychologist would then determine the complete personality by individual examination of the experiential factors relevant for that individual. He would make use of that knowledge of the etiology of complexes, of attitudes, compensation and defence mechanisms, already previously established in personality studies and the work of Freud, Adler, Jung, Kretschmer, Jaensch, Klages, Künkel, and their schools. This point of view has the merit of dealing with the simpler aspects of personality first. It discards none of the work that has preceded, holding out some prospects of harmonising the apparently hopelessly conflicting theories existing to-day.

The Temperament scheme required to answer this purpose must fulfil the following conditions:—

1. The relevant Temperament behaviour qualities must be reduced to a minimum number of simple, distinct, and fundamental variables or behaviour units. As "relevant behaviour qualities" must be taken those designated by such terms and descriptions as "readily enthusiastic," "quickly offended," "impulsive," "works by fits and starts," "gets down to a task and finishes it there and then," "changes easily from one mood to another," "always occupied in spare time," "finds it difficult to get rid of unpleasant thoughts," "calm and quiet," "quick, restless, or jerky in movement," and the like. Excluded are personality attributes such as "tolerant," "credulous," "keen on personal distinction," "kind towards inferiors," "frequenter of social gatherings," "seeker of solitude," "artistic," "lover of games of chance," "revolutionary in politics," "ambitious," "warmly religious," "courageous," "autocratic," and the like. They are too much a product of the social environment to be useful in the detection

of Temperamental variables. Admittedly, the Temperamental qualities selected are not free from this influence. Yet they are a sample of behaviour qualities in which tempo, continuity, consistency, urgency, and intrinsic quality (cognitive, affective, or conative) of reaction are clearly discernible. Such behaviour forms, which are the direct expression of the quality and level of reaction of the organism, can be most clearly observed in the behaviour of the young child. They are discernible also in the more complex conduct of adults of all ages. The other qualities quoted are inconceivable without a prolonged social development; they are the substance of personality.

By following this procedure one is reasonably certain of discovering general factors, behaviour variables functioning at some intensity or other in everyone. This is essential for a dynamic Temperament theory in which every individual must be immediately comparable with every other individual in respect of Temperament behaviour and in which no one must be unclassifiable.

In the Temperament qualities quoted the disturbing influence of environmental development is approximately ruled out. Hence static factors which result from environmental and experiential uniformities in the lives of people having a particular native equipment in common, which makes them susceptible to certain influences, will not occur.

2. We must know the complete behaviour function of each factor or variable—*i.e.* the type of behaviour it will tend to produce under constant average environmental conditions.

3. As these variables will always be acting together in some ratio or other, they are likely to modify each other's function. If that should be the case the nature of that modification and its significance for the total behaviour pattern must be known.

4. In practice these factors will be operating under widely divergent environmental and experiential conditions. The influence, if any, of such conditions on (*a*) the organic basis of the factors themselves, (*b*) the constancy or development of their behaviour function, must be known.

5. The nature of the organic process underlying each behaviour variable should be determined for practical as well as theoretical reasons. Such knowledge would facilitate the drawing up of clinical tests to measure the strength of each variable accurately.

6. For the wider study of personality, the personality implications of variable ratios (*i.e.* Temperament types) should be known. A study must be made of the genetic connection between each type and the numerous personality Gestalten such as the Inferiority Complex, Oedipus Complex, integration, autism, over-compensation, etc.

II. Procedure.

This paper is only concerned with the first part of the task outlined above. It deals with the search for variables and the determination of their function as Temperament units. The research was conducted partly in South African partly in Scottish schools, under approximately similar conditions.

A. *Search for Tentative Variables.*

An analysis was made of past and current Temperament Theory with the intention of discovering regularities, which might suggest likely factors. These regularities do indeed occur, and can be grouped under three headings:

1. Differences in respect of general stimulability and of speed, continuity, perseveration of responses.

In some form or order, differences of this kind occur in nearly all typologies and theories, even in those where the emphasis is on another factor such as emotionality. Richerand (5) made variability in speed and continuity at a certain level of reaction the basis for a classical typology. Both McDougall's (6) and Shand's (7) definition of Temper involve these differences, while they are also the substance of Kretschmer's (2) Psychic Tempo and Psychomotility. In the concept of Perseveration or Secondary Function, investigated by Gross (8), Müller (9), Heymans (10), Wiersma (11), Pfahler (12), Spearman (3) and his school, this same cognitive factor is again found.

Constance Bloor's (13) excellent analysis also led her to "some physiological functioning associated with initial speed of reaction and maintenance of original reaction level." Pavlov's (14) distinction between excitatory-inhibitory types points to the physiological reality of these differences.

2. Differences in susceptibility to and intensity of affective behaviour. This factor is the sole determinant of a large number of theories. Temperament is generally understood to refer to differences in the arousal, duration, and discharge of the emotional response. Such differences as those discussed under the previous heading are observed; but only as an aspect of the Emotional process and not as functions of a factor with an apparently distinct existence. Differences in respect of Emotional behaviour constitute the core of the Psychiatric theories. Burt (15) postulates a general Emotional factor; Shand (7) and McDougall (6) also assign central significance to it.

Finally, the endocrine glands, considered of great Temperamental importance, are closely connected with Emotional behaviour, of which, together with autonomic nervous activity, they may be the organic basis.

3. Differences in strength and frequency of Volitional Action.

These are generally stressed even by those investigators who do not

incorporate a volitional factor in their ultimate theoretical statement on the nature of Temperament. Kretschmer (2), for instance, mentions tireless energy and great volitional persistence as a characteristic of his pyknic type. McDougall (6) states: "There can, I think, be little doubt that . . . the man who is naturally steadfast and persistent in respect of some impulses will show the same quality, no matter what motives be at work in him." This persistence is unconnected with the strength and urgency of impulses and desires. Similarly Webb's (16) "W" factor determines perseverance in the face of obstacles. Among the qualities correlated with the "W" factor lately isolated by Cattell (17) energy and perseverance are mentioned. Volitional action is the basic factor in the Downey (18) scale, measuring a Will-Temperament, while Ach's (19) typology is based on differences in "feeling and willing capacity." These regularities suggest three variables, one cognitive, one affective, one conative. All are tentatively identifiable with simple behaviour qualities. Two are roughly referable to organic processes; the organic nature of the third is more obscure, but the work of both Webb and Cattell affords evidence of its reality.

B. *Examination of the Heymans Typology.*

The only personality scheme in which all these three factors have been recognised as distinct is that of Heymans and Wiersma (20), who used them as variables for a typology. They occur as:

1. Primary-Secondary Function.
2. Emotionality.
3. Activity.

Heymans (10) defines them as follows: "In general we call someone Emotional on the basis of the frequency and strength of his affective reactions, in proportion to their causes; Active on the basis of frequency and energy of his activities, in proportion to their motives; Primary or Secondary Functioning according to the degree in which cognitive and affective processes 'perseverate' (German: *nachwirken*), in proportion to their importance." These three factors, as used by Heymans, may be further elucidated as follows:—

(*a*) Mental processes of all kinds exercise a Primary Function while they are fully conscious, a Secondary Function when they are no longer in the focus of consciousness or unconscious (as memory traces, etc.). Either one or the other can be habitually predominant in the mental life of an individual. This Secondary Function manifests itself in the modifying and supplementing of, or interfering with the present Primary mental content, chiefly through spontaneous or associative re-arousal of previous mental contents, partly through an unconscious "braking" (German: *Hemmung*) effect.

By means of investigations on threshold for flicker, adaptation to light, and to electric current, Wiersma (11) has demonstrated that these differences have a neural basis, the exact nature of which is as yet uncertain.

(*b*) In respect of Emotionality, it must be noted that this variable does not determine differences in duration and readiness of arousal of Emotional Reactions. It is only concerned with the relative intensity and urgency of the emotional process.

(*c*) Activity means to Heymans "Volitional Activity" which can be both overt and ideational. If two individuals are both equally aware of the implication of a certain action, and the result of that action is equally desirable to both, then we may say that the motive for their action is similar in both cases. Yet we might find the one much more readily performing that action than the other. The first would be Active, the second Inactive.

If we now examine the work of Heymans and Wiersma and their school a little further, we find experimental facts about these three factors of a most promising kind for the purpose we have in view.

Their chief research we are concerned with here consists of a questionnaire study of 2523 adults, rated on a large variety of personality traits by Dutch medical practitioners intimately acquainted with those they were judging. This questionnaire contains a wealth of most divergent personality and Temperament traits. A few of these Heymans used as criteria for his three factors. On the basis of a majority verdict of these criteria subjects were adjudged Primary or Secondary Functioning, Active or Inactive, Emotional or Non-Emotional. From this, eight different combinations result to each of which Heymans applied a type name as follows:—

Secondary—Active—Emotional: "Passionate Type";
Primary—Active—Emotional: "Choleric Type";
Secondary—Active—Non-Emotional: "Phlegmatic Type";
Primary—Active—Non-Emotional: "Sanguine Type";
Secondary—Inactive—Emotional: "Sentimental Type";
Primary—Inactive—Emotional: "Nervous Type";
Secondary—Inactive—Non-Emotional: "Apathetic Type";
Primary—Inactive—Non-Emotional: "Amorphous Type."

He calculated the percentage of cases in each type group possessing each questionnaire quality and compared this with the percentage incidence of that quality in the whole group. If this percentage exceeded the average, he considered the trait concerned significant of that type. As in many questionnaires a number of traits were not scored wherever the rater was in doubt, both the percentage incidence and the differences

between them were very small and hardly significant by present statistical standards. Heymans relied largely, however, on the fact that most of these small differences point in the same direction, that they are derived from very large groups, and that they establish for each type a distinct behaviour pattern, consistent with the *a-priori* nature of the particular combination of factors it represents. The cumulative effect of his small correlations is undoubtedly significant.

Nevertheless, as it stands, the Heymans typology will not do for our purpose.

1. It is chiefly a personality typology, and as such subject to inevitable flaws. Heymans was aware of its limitations, and in an unsystematic way allowed for many. He says, for example: "Further, one cannot exclude the possibility that through the agency of certain (especially ethical) characteristics, of which this classification takes no account, the operation of its fundamental function is altered or compensated for."

2. The criteria he used are unsatisfactory. Especially those for Secondary Function are mainly personality traits or strongly correlated with Emotionality. For Emotionality he had only one very poor criterion. He made no attempt to weight them according to selective power.

3. The most serious drawback is the lack of a systematic study of his factors. No attempt is made to establish their precise nature as behaviour units, the necessary attributes of which we have enumerated. Scattered throughout his study are acute observations on the relationship between the types and environmental influences; what we have called their personality implications. One has to proceed by inference, however, and no complete statement emerges. Heymans points out "that this classification does not pretend to be the only true or good one, not even a 'natural' one. It is possible to divide a group of phenomena from very different points of view and of these different possible classifications there is not just one right, and all the others untrue: but they are all more or less useful." Heymans convinced himself of the usefulness of his scheme to his own satisfaction. He recognises the need for further investigation of the new problems raised by his pioneering work.

C. *Method Adopted.*

The direct object of this research has therefore been to examine the Heymans variables in respect of those requirements which have been postulated for an adequate Temperament analysis. The broad lines of the Heymans questionnaire technique have been adopted. This method of approach was chosen in preference to that used by Cattell (17), among others. His subjects were rated on several heterogeneous personality and Temperament attributes, drawn from a number of outstanding studies.

The intercorrelations between the various items were examined for general and group factors by means of the tetrad difference criterion, and an attempt was made to find a psychological explanation for these.

On our initial hypothesis that Temperament is reducible to a number of variables which must function in every person in some ratio or other, many behaviour qualities will necessarily be a product of two or more factors. This would considerably increase the difficulties of analysis by means of Cattell's approach.*

The method of putting to the test a number of variables assumed to exist after careful analysis of previous work, has, therefore, considerable merit with this type of material. What is lost in mathematical precision is gained by directed effort and such *a-priori* assumptions as are made can be finally tested by an examination of the resulting correlations.

Four investigations have already been conducted by the Heymans school, on large and diverse groups. Further corroboration of their findings in principle would be strong evidence of their reliability, if not of their validity.

D. *Selection of Experimental Subjects.*

For various reasons it was decided to use school children as subjects. Character and Personality qualities have not developed to the same extent as in the adult, and are more easily separable from the Temperamental basis. There is less chance of fundamental trends having been obliterated by habit-formations or inhibitions.

It is possible also to fulfil the condition of uniformity in the rating. The children are observed against the same objective background; their reactions to class-room discipline and school activities are the subject-matter of the questionnaire. The observers themselves tend, through training and experience, to assume a fairly uniform attitude towards this material. It seems reasonable to suppose that they have some psychological insight into the child mind, as it manifests itself in the daily school routine.

Furthermore, it was possible, in many cases, to select those teachers who seemed most suitable for the task. Many knew their pupils out of school, in boarding establishments and through sporting activities. Accordingly 645 children, age range 8–16 years, were examined. In order to have a representative group they were chosen from widely divergent environments. The following table illustrates this selection:—

* None of the factors actually found by Cattell are of the simple type required. They are complex Personality Gestalten such as "Surgency," Webb's character factor "W," and the Cyclothyme attitude, which bears out what was said in criticism of his method.

Scotland.		South Africa.	
1. Urban High Schools . .	76 cases.	Urban High Schools . .	45 cases.
2. Country High Schools .	107 ,,	Suburban Secondary Schools .	62 ,,
3. Urban Elementary Schools	78 ,,	Urban Coloured Schools . .	66 ,,
4. Country Elementary Schools	100 ,,	Orphanage Schools. . .	38 ,,
5. Industrial Schools . .	73 ,,		
Total .	434 ,,	Total .	211 ,,

The children in group 1 (Scotland) are drawn from upper forms of superior High Schools in Edinburgh and Glasgow, those in groups 2 and 4 from Wigtownshire, an agricultural district. Group 4 consists of children of very mixed environments. Group 3 contains 59 Non-Qualifying pupils from Dumbarton (*i.e.* pupils who failed to pass the admission examination for the High School); group 5 are institutional cases, drawn from the worst type of urban environment, the majority being delinquent. The South African children in group 1 correspond to the Scottish High School selection except that they are taken from lower forms; those in group 2 are of a more mixed environment, corresponding to the Scottish Country High School group; group 3 come from thoroughly poor environmental conditions; the origins of the institutional group 4 are in some cases not much better than the Scottish industrial group.

E. *Questionnaire.*

The questionnaire used is based on that of the Heymans-Hugo (21) School Inquiry of which such features as seemed useful were taken over. It contains but few questions on indirect, or personality qualities, and for the most part has been designed to present as objective a set of data as possible.

Has, Is, or Does the child—

1. (*a*) Regularly work with application and zest?
or (*b*) With periods of "slacking" and "easing off"?
or (*c*) Lazy?

2. (*a*) Usually attentive?
or (*b*) Easily distracted?
or (*c*) Playful?
or (*d*) Often busy with other things than the lesson? (Scribbling, scratching, or drawing on desk.)

3. Immediately cease attending at the end of a lesson or bell-ring? (Puts books away or stops writing and starts with something else.)

4. Inclined to sulk? (*E.g.* after supposed unjust punishment.)

5. (*a*) Retain the previously learned? (The information "sticks," as witnessed by questions asked by the child at a later discussion of a kindred subject.)
or (*b*) So heard, so forgotten? (Never thinks of the matter again, or does not recollect it.)

or (*c*) Thinks over those matters which were found interesting, but yet finds it easy to dismiss everything from the mind and attend completely to something else?

6. (*a*) Impulsive?
or (*b*) Cautious?

7. (*a*) Cheerful?
or (*b*) Depressed?
or (*c*) Alternatively either?
or (*d*) Always even of mood?

8. (*a*) Irritable?
or (*b*) Quickly offended?
or (*c*) Good humoured?
or (*d*) Unable to be angered?

9. (*a*) Accurate? (Punctual at school, work finished at required time.)
or (*b*) Inaccurate? (Careless mistakes, forgetful, comes late.)

10. (*a*) Try to grasp a problem, think it over and form his own opinion?
or (*b*) Accept and merely learn by heart what is taught?

11. (*a*) Remember what is learned clearly?
or (*b*) Inaccurately and in a muddled fashion?

12. (*a*) Quick and ready in answering?
or (*b*) Slow?

13. (*a*) Constant in friendship?
or (*b*) Inclined to be very "thick" for a while and to break off completely and develop a craze for someone else?

14. (*a*) Restless and inclined to fidget? (Never sits still, preference for rough games.)
or (*b*) Calm and quiet?
or (*c*) Lifeless and inert?

15. (*a*) Get down smartly to set class-work and finish it?
or (*b*) Inclined to dawdle and waste time?

16. When in difficulties:
(*a*) Inclined to give up?
or (*b*) Try to fight through with determination?
or (*c*) Ask for help?

17. After school hours occupied at sport, or walking, or hobbies, or handwork, or reading or music?

18. Member of athletic or gym. club?

19. Member of debating club? Serve on committee and so be in the limelight?
(These two questions were deleted in scoring. They are applicable in Holland, where sporting and social activities are not connected with the schools; if a child deliberately seeks membership of some outside organisation for such purpose it would be a fair indication of his Activity. In British schools this is obviously different.)

20. When scolded or reproved:
(*a*) Inclined to cry?
or (*b*) Be rude?
or (*c*) Argue?
or (*d*) Sulk?
or (*e*) Assume an annoying and defying attitude in desk?
or (*f*) Take it calmly and with resignation?

21. At examinations:
(*a*) Calm?
or (*b*) Nervous?

22. (*a*) Depressed and slightly pessimistic?
or (*b*) Usually bright and optimistic?

23. (*a*) Quickly enthusiastic? (About people, historical or living, nature, art, etc.)
or (*b*) Indifferent?
or (*c*) More reserved in expression?

24. After making a bad mistake:
(*a*) Angry?
or (*b*) Discouraged?
or (*c*) Eager to correct and make good?
or (*d*) Indifferent?

25. (*a*) Emotional? (Feelings frequently exhibited.)
or (*b*) Non-Emotional? (Cool, controlled, undemonstrative.)
or (*c*) Feelings not on the surface, but probably yet there?

26. (*a*) Critical? (Disparaging of others, inclined to notice preferably bad traits.)
or (*b*) Idealising? (Inclined to take the best, or too good a view of human nature.)
or (*c*) Neither?

27. (*a*) Headstrong? (Inclined to passive resistance, persevering in something wrong through false sense of shame.)

28. (*a*) Polite and affable?
or (*b*) Insolent and rude?
or (*c*) Indifferent in manner?

29. (*a*) Inclined to show a temper on certain occasions? (When teased, punished, thwarted, etc.)
or (*b*) Not?

30. (*a*) Inclined to be a ringleader, or involved always in trouble, scrapes and naughtiness?
or (*b*) Belonging to the law-abiding and well-behaved?
or (*c*) Merely apathetic?

31. Is the pupil in your opinion an active, or an inactive type? Does the pupil display mainly intellectual activity, or mainly physical activity, or both, or neither in any marked degree, or definitely neither?

F. *Criteria and Method of Tabulation.*

The subjects were next classified by means of three sets of criteria. In respect of each variable they are not placed in a continuous scale but are divided into two broad classes, one being taken as positive, the other as negative, *e.g.*:

Positive: the Secondary Grouping.
Negative: the Primary Grouping.
Positive: the Active Grouping.
Negative: the Inactive Grouping.
Positive: the Emotional Grouping.
Negative: the Non-Emotional Grouping.

In the following analysis degrees of positiveness or negativeness are not considered, the subjects being either Secondary Functioning or Primary Functioning, Active or Inactive, Emotional or Non-Emotional. This was done (*a*) because the criteria did not allow of very accurate determination of strength of the variable, beyond indicating whether it was positive or negative; (*b*) because only the pattern corresponding to the average, positive, or negative strength was required. Although the variables are true continuous variables, it will not affect the result materially if they are treated as dichotomous. We shall merely find that to a slight extent some of the traits belonging to the positive form of the variable are exhibited by individuals who are only just included in the negative class and *vice versa*. For practical clinical purposes some test or criterion scale which does discriminate more finely will have to be devised, but that does not concern us here.

An examination of Hugo's (21) results reveals that his criteria vary widely in selective power. Some, indeed, are useless, whereas a number of ordinary questions show themselves to be highly diagnostic. The criteria used in this investigation are chosen mainly from Hugo's questionnaire. They are weighted on the basis of the diagnostic value they were shown to possess by Hugo's data. For a number of other criteria, namely (1) those taken from the Heymans adult questionnaire, (2) some extra alternatives introduced to elaborate Hugo's questions, (3) some original

criteria which seemed likely to be useful, such a basis for weighting was lacking. Weights were therefore tentatively applied by making use of such knowledge of the variables as could be gathered from Heymans's work. Next, a preliminary classification of about 200 cases was made to enable all weights to be adjusted; after which the entire group, including the 200 preliminary cases, could be finally classified. Two criteria, the selective value of which was uncertain, were used throughout corroboratively in those cases where a neutral score was obtained (Table A).

TABLE A.

Primary—Secondary Function.		Activity—Inactivity.		Emotionality—Non-Emotionality.	
Question.	Criterion value.	Question.	Criterion value.	Question.	Criterion value.
1*a*	1	1*c*	−3	20*a*	1
b	−3	14*c*	−4	*d*	1
2*a*	2	15*a*	2	21*a*	−1
b, *c*, *d*	−3	*b*	−3	*b*	1
3	−2	16*a*	−1	23*a*	2
5*a*	1	*b*	−1	*b*	−3
b, *c*	−1	*c*	3	24*a*	3
6*a*	−2	17	+3 −3	*b*	2
b	2	..	..	*c*	−3
7*a*	−1	..	..	25*a*	(3)
b	1½	..	..	*b*	(−3)
c	−3	..	..	*c*	(1)
d	3	31	(+4 −4)	..	..
13*a*	1	..	..	..	..
b	−1	..	..	..	..
14*a*	−2	..	..	..	..
b	1½	..	..	..	..

Questions 31 and 25 used mainly corroboratively.

Individuals were rated as Secondary or Primary Functioning, Active or Inactive, Emotional or Non-Emotional according as the algebraic sum of each of these sets of criteria was positive or negative.

In a number of cases a zero score was obtained in respect of the Activity and Emotionality variable. After supplying detailed definitions and a finely graded rating scale, we sought further information from teachers connected with these cases. Where difficulties still remained a decision

was made one way or another with the aid of explanatory notes frequently appended to the questionnaires.

Imperfect criteria are partly, but not wholly, responsible for these difficulties. Numerous people are in fact half-way between the two extreme aspects of a variable. Their inclusion will not vitiate the present work to any extent. Statistical treatment will reveal the functional differences between the positive and negative aspects sufficiently clearly. The problem raised by these apparently undeterminate people in connection with a temperament scheme of practical value will be dealt with at a later stage.

Every subject being rated on all three variables, our group resolved itself into eight sub-groups as follows:—

Secondary—Active—Emotional (S.A.E.):	103	cases.
Primary—Active—Emotional (P.A.E.):	114	,,
Secondary—Active—Non-Emotional (S.A.N.):	144	,,
Primary—Active—Non-Emotional (P.A.N.):	41	,,
Secondary—Inactive—Emotional (S.I.E.):	14	,,
Primary—Inactive—Emotional (P.I.E.):	74	,,
Secondary—Inactive—Non-Emotional (S.I.N.):	49	,,
Primary—Inactive—Non-Emotional (P.I.N.):	106	,,

Going through the questionnaire item by item I next determined how many individuals in each of these sub-groups, or types, possessed the quality referred to in each question. For this purpose each alternative was treated as a separate question. These numbers were then expressed as percentages of the total number in the sub-group. I shall refer to this as the "percentage incidence" (p.i.) of a quality in a type (Table II).

Before interpreting the result thus obtained I must first demonstrate:

1. The reality and distinctness of the variables.
2. The function of each singly.

Calculation of the percentage incidence of each quality in the dichotomous grouping of each variable will not meet the case. On account of the disparity in numbers between the samples obtained of the types, the Secondary group, for instance, would be overwhelmingly a Secondary Active Group. The behaviour qualities found significant for this group would in reality be those characteristic of Secondary Function and Activity operative together. A similar difficulty arises in the other groups. Among the cases classified as Primary there are more Inactives than Actives. In the Active group the Secondary predominate, and in the Emotional group the Primary. A consideration of the Secondary group will illustrate the procedure finally adopted.

The average of the percentages obtained for each quality in the four

Secondary types was taken and treated as the percentage incidence of that quality in a Secondary Functioning group of 310 cases, with the other two variables constant. This procedure involves the assumption that the selections obtained of the types are equally reliable samples, giving equally accurate reflections of the true behaviour patterns corresponding to each type. This assumption is only seriously questionable in the case of the S.I.E. group, which consists of but 14 cases. As I shall show in due course, the incidence of qualities in this small group reveals a distinct and consequent pattern which is consistent with the implications of the three variables, deducible from the larger S.A.E. and S.A.N. samples. Hence, in so far as the two larger groups are true samples, so will the S.I.E. group be a true sample. The fact that our behaviour patterns are in main agreement with those of Heymans, Wiersma, and Hugo is additional justification for this procedure. The average percentage incidence calculated in this way can therefore be considered a real percentage incidence for a group of 310 Secondary cases, with other variables constant. In further statistical work it will be treated as such. The method adopted offers the only feasible way of equating the influence of variables, other than the one under investigation. With material of this type it is not always possible to stick to the strict statistical paths, but in view of the facts adduced above our aberration seems justifiable.

The difference between the p.i. of a quality in the positive and negative groups of a variable, and its comparison with the same differences obtained with the other variables, will reveal of which variable the quality in question is a function.

For example, for Question 3: "Does the child immediately stop attending at the end of a lesson?" the p.i. in the positive or Secondary group of the Function variable is 6·2 per cent.; in the negative or Primary group 68 per cent. Difference (Activity and Emotionality constant): −61·8 per cent. For the other two variables: 33·1 per cent. in the Active group, 40·9 per cent. in the Inactive group. Difference (Function and Emotionality constant): −7·8 per cent. 35·4 per cent. in the Emotional group, 38·6 per cent. in the Non-Emotional group. Difference (Function and Activity constant): −3·2 per cent.

The percentage differences in this example indicate that the quality in question is associated with the negative form of the Function variable: it is a Primary Function quality. It is first necessary, however, to determine whether these percentage differences are statistically significant. This was done by means of Yule's (22) formula:

$$\epsilon^2 = \frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}$$

p_1 represents the proportion of cases in the one group displaying a certain

quality, p_2 the proportion of cases in the other group displaying the same quality.

$$q_1 = 1 - p_1, \qquad q_2 = 1 - p_2.$$

n_1 is the number of cases from which p_1 was derived (in our case the number in the positive group). n_2 is the number of cases from which p_2 was derived (the number of cases in the negative group).

From this formula one finds ϵ which is the S.D. for each p.i. difference.

$$\frac{p_1 - p_2}{\epsilon}$$

will then give its reliability. The validity of the use of this formula is subject to the assumption involved in our calculation of p and n.

Thus by means of this method we obtained for each questionnaire quality:

1. Its p.i. in the positive and negative sections of the whole group of 645 cases when divided on the basis of (*a*) Function, (*b*) Activity, (*c*) Emotionality.

2. The difference between its p.i. in the positive and negative groupings of each variable.

3. The significance of those differences.

4. A comparison between its three p.i. differences for the three variables respectively.

From this material the existence and function of the three variables can be deduced.

TABLE I.

To Illustrate the Existence of the Three Variables, from a Comparison of the Average Percentage Incidences of the Criteria for each Aspect of each Variable, in each of the Dichotomous Groupings.

	S.F. group (310).	P.F. group (335).	Average per cent. difference.	Ratio average per cent. difference to S.D.	Active group (402).	Inactive group (243).	Average per cent. difference.	Ratio average per cent. difference to S.D.	Emotional group (305).	Non-Emotional group (340).	Average per cent. difference.	Ratio average per cent. difference to S.D.
Secondary Function Criteria . . .	66·5	24·9	+41·6	12	51·4	39·8	+11·6	2·9	43·3	48·2	− 4·9	1·3
Primary Function Criteria . . .	10·9	45·6	−34·7	11	27·6	31·8	− 4·2	1·1	44·8	40·1	+ 4·7	1·2
Activity Criteria . .	47·8	32·2	+15·6	4·1	73·2	16·5	+56·7	18	39·5	40·4	− ·9	·2
Inactivity Criteria . .	22·7	31·5	− 8·8	2·5	13·6	49·2	−35·6	10	26·4	27·9	− 1·5	·4
Emotionality Criteria .	22·7	25·8	− 3·1	·9	22·6	25·9	− 3·3	·9	41·4	9·7	+31·7	9·5
Non-Emotionality Criteria	39·3	47	− 7·7	2	36·2	50·1	−13·9	3·4	18·5	56·7	−38·2	11

III. Results.

1. *Reality of Variables.*

Table I gives the average per cent. incidence of criteria, both in the groups selected by their means and in the dichotomous groupings of the remaining variables. The incidence of Secondary Criterion qualities in the Secondary group exceeds the same incidence in the Primary group by 41·6 per cent., which is 12 times larger than the S.D. of the difference; the incidence of the Primary Criterion qualities in Primary group exceeding the same incidence in the Secondary group by 34·7 per cent., which is 11 times larger than the S.D. On the other hand, the difference between the p.i. of (*a*) Secondary Criterion qualities, (*b*) Primary Criterion qualities in the Active and Inactive groups is but 2·9 times and 1·1 times the S.D. respectively; in the Emotional and Non-Emotional groups 1·3 and 1·2 times.

We can deduce from these figures that: *the Secondary and Primary Function criteria respectively cohere and are the expression of the opposite aspects of some underlying unit, different from those on the basis of which we have obtained the Active—Inactive, Emotional—Non-Emotional groupings.* This amounts to saying in the more familiar language of a different statistical method that the separate criteria for the Secondary group, as well as for the Primary group, intercorrelate, but that there is a high negative correlation between the pools of the two sets, and no correlation or a hardly significant correlation between the pools of Secondary or Primary criteria, and those for the Activity and Emotionality variables.

An examination of Table I shows that all this is equally true of the Activity and Emotionality variables.

We have therefore demonstrated that the three variables exist in so far as the behaviour qualities used as criteria are concerned.

Whether this subjective unity does in fact correspond with the postulated basis of the variables is another question. A unity it is, however, and further evidence from the function of these variables may confirm the existence of this basis or reveal another one. In the further determination of the function of variables the criterion qualities will be considered indiscriminately with all others.

The data are not definite on the complete distinctness of the three variables. Apparently there is some affinity between the positive aspects of Function and Activity. Is this overlap real or apparent? Special attention will be given to this question.

For the sake of brevity and clearness of exposition, the questionnaire qualities, including the criteria, except Nos. 5, 17, 31,* have been roughly divided under the following headings:—

* Question 5 was deleted because it was generally misunderstood to refer to excellence of memory rather than to perseveration. We had no option but to include it in our

1. *Way of Working.*
   (*a*) Qualities of attention and application.
   (*b*) Qualities of distraction and lack of application.
2. *Qualities affecting School performance.*
3. *General Conduct.*
   (*a*) Socially valuable conduct qualities.
   (*b*) Socially less valuable conduct qualities.
4. *Determination of Mood.*
5. *General Indifference.*

All the following tables give the p.i. of these qualities in dichotomous groupings of the variables. The ratio of percentage differences to their S.D. has only been indicated in these cases where it is difficult to judge by inspection.

A table has also been added (Table II) giving the percentage incidence of qualities in the eight type groups. It illustrates the function of variables acting in combination, and will, furthermore, serve as an additional check on the deductions made from the p.i.'s in our dichotomous groupings.

TABLE II.

Percentage Incidence of Temperament Qualities in Eight Type Groups (Variable Ratios).

	S.A.E. (103).	S.A.N. (144).	P.A.E. (114).	P.A.N. (41).	S.I.E.* (14).	S.I.N. (49).	P.I.E. (74).	P.I.N. (106).	Average.
1*a*. Work regularly with application and zest.	95	91	35	21·5	11	51	8	1	49·5
b. With alternate periods of laziness and hard work.	3	7·5	64	71·5	1	39·5	73·5	73·5	41·5
c. Lazy	(1)	(1·5)	(1)	(7)	(2)	(10)	(17·5)	(27·5)	(8·5)
2*a*. Usually attentive	98	97	37	35·5	13	88	5·5	9·5	57
b. Easily distracted	2	2	38	35·5	..	10	60	60	27
c. Playful	1	4	36	16·5	..	..	28	10·5	13·5
d. Often busy with other things than lessons.	..	1·5	17	16·5	1	4	26·5	40	14·5
3. Immediately cease attending at end of lesson.	6·5	5·5	58·5	62	1	6	69·5	81	38·5
4. Inclined to sulk (after supposed unjust treatment)	12·5	4	38	21·5	4	14·5	60	42	26·5

criterion table, because it was used as such; actually it differentiated between P.F. and S.F. to some extent, on the ground of memory differences, but it would serve no useful purpose including it in our detailed discussion. Question 17 is too much a personality attribute to warrant discussion here. Question 31 was only used corroboratively.

* Owing to the smallness of the S.I.E. group, the incidence of qualities in this group has not been turned into percentage form, though percentages have been calculated for subsequent tables.

TABLE II—*continued.*

	S.A.E. (103).	S.A.N. (144).	P.A.E. (114).	P.A.N. (41).	S.I.E.* (14).	S.I.N. (49).	P.I.E. (74).	P.I.N. (106).	Average.
5*a*. Child retains the previously learned	83·5	84·5	66	47·5	7	26·5	16	9·5	53
b. So heard, so forgotten	6·5	10	19	38	2	65	74·5	76	35
c. Thinks over what is found interesting, but can dismiss everything from mind.	(9·5)	(5)	(15)	(12)	(3)	(6)	(8)	(15)	10·5
6*a*. Impulsive	27	3	82	50	2	..	73·5	37	37
b. Cautious	72	97	17	52·5	12	100	24	59	61·5
7*a*. Cheerful	61·5	42	63	59·5	3	10	36	38	45·5
b. Depressed	7·5	4	2	2·5	2	20·5	5·5	15	7·5
c. Alternately either	7·5	3·5	36	31	4	8	51·5	37	23·5
d. Always even of mood	30·5	54	3·5	9·5	5	67	8	22	28·5
8*a*. Irritable	2	·5	18	16·5	1	4	28	13·5	10·5
b. Quickly offended	19	5	23·5	16·5	2	4	38·5	24	18·5
c. Good humoured	78	78·5	61·5	69·5	7	63	36	55	64
d. Unable to be angered	..	16	2·5	..	4	32·5	1·5	12·5	9·5
9*a*. Accurate (punctual at school, work done in time, etc.).	93·5	9·3	60	59·5	5	39·5	6·5	11·5	56
b. Inaccurate (careless mistakes, etc.)	6·5	7	39	40·5	7	59	92	90	42·5
10*a*. Attempt to grasp a problem, form an opinion.	70	76·5	62	52·5	4	10	17·5	14·5	48
b. Accepts and learns by heart what is taught.	29	23	38	47·5	10	88	81·5	85	51
11*a*. Remembers what is learned clearly and accurately.	85·5	90	70	50	2	16·5	8	11·5	53
b. Remembers inaccurately and in muddled fashion.	12·5	10	30	47·5	12	81·5	90·5	89	45·5
12*a*. Quick and ready in answering	70	55·5	84·5	45	2	6	36	11·5	48
b. Slow in answering	26	44·5	14·5	52·5	12	94	61	89	50·5
13*a*. Constant in friendship	81·5	83	50·5	64·5	10	77·5	42·5	47·5	64·5
b. Inclined to be very thick and then break off.	2	4	35	16·5	1	10	37·5	33·5	19
14*a*. Restless and inclined to fidget	11·5	5	91	62	1	2	73·5	45·5	39
b. Calm and quiet	86·5	93·5	8	35·5	9	45	8	25	48·5
c. Lifeless and inert	..	1·5	..	..	4	57	17·5	30·5	12·5
15*a*. Get down smartly to set class-work	94	97	68	74	6	43	17·5	5	60
b. Inclined to dawdle and waste time	5	2	32	26	7	53	80	95	38·5
16*a*. Inclined to give up	6·5	7	29	16·5	6	61	81·5	81	37
b. Try to fight through with determination.	70	80·5	40	62	1	10	2·5	4	42
c. Ask for help	21	13·5	34	24	7	29	14·5	15	21

* Owing to the smallness of the S.I.E. group, the incidence of qualities in this group has not been turned into percentage form, though percentages have been calculated for subsequent tables.

TABLE II—*continued.*

	S.A.E. (103).	S.A.N. (144).	P.A.E. (114).	P.A.N. (41).	S.I.E.* (14).	S.I.N. (49).	P.I.E. (74).	P.I.N. (106).	Average.
17. Music	14·5	15·5	11	9·5	3	8	6·5	10·5	12
Handwork	11·5	13·5	10	9·5	2	4	1·5	5·5	9
Sport	77	66·5	88	86	10	55·5	52	60	69·5
Reading	50	53	50	35·5	7	34·5	33·5	21	41·5
Hobbies	27	15·5	20	12	4	12·5	28	15	19·5
20*a*. When scolded inclined to cry	20	3	12·5	7	7	10	21·5	10·5	12·5
b. When scolded inclined to become rude.	3	..	2·5	2·5	..	..	13·5	3	3
c. When scolded inclined to argue	4	1·5	19	19	..	6	14·5	11·5	9·5
d. When scolded inclined to sulk	11·5	4	35	16·5	1	16·5	49·5	33·5	22·5
e. When scolded inclined to adopt annoying attitude.	3	1·5	4·5	..	..	2	6·5	4	3
f. When scolded inclined to take it calmly and with resignation.	55	87·5	40	62	5	71·5	21·5	51·5	56
21*a*. At examinations, calm	47	87	56	78·5	2	77·5	47·5	81	66·5
b. At examinations, nervous	56·5	13·5	44	21·5	12	22·5	52	20	34
22*a*. Depressed and slightly pessimistic	17·5	16	16	21·5	8	73·5	33·5	40	27·5
b. Usually bright and optimistic	80	75	81	78·5	6	22·5	58·5	58	67·5
23*a*. Quickly enthusiastic over things, people, events, interests.	56·5	10	80	9·5	3	..	44	3	31·5
b. Indifferent	6	13·5	9	47·5	6	73·5	36	87·5	33·5
c. More reserved in expression of appreciation.	37·5	76·5	10	43	5	29	15	11·5	34·5
24*a*. After making a bad mistake, angry.	9·5	·5	23	..	3	..	26·5	3	10
b. After making a bad mistake, discouraged.	26	6·5	17	9·5	6	24·5	26·5	14	17·5
c. After making a bad mistake, eager to correct and make good.	71	80	57·5	45	5	12·5	20	7·5	47
d. After making a bad mistake, indifferent.	1	12	11	45	1	67	24	77	28
25*a*. Emotional. Exhibits feelings frequently and readily.	67·5	·5	98	4·5	9	2	89·5	6·5	41
b. Non-Emotional. Cool, controlled	6·5	82·5	..	76·5	..	90	4	71·5	43·5
c. Feelings not on surface, but probably there.	(22)	(17)	(2)	(19)	(4)	(6)	(5·5)	(22)	(14)
26*a*. Critical	24	23	48	35·5	1	12·5	58·5	37	33·5
b. Idealising	41·5	44	27	21·5	4	30·5	8	13·5	28
c. Neither	(29)	(21·5)	(20)	(31)	(9)	(36·5)	(25·5)	(38)	28
27. Headstrong (inclined to passive resistance).	11·5	5	30·5	21·5	1	8	45·5	27·5	20
28*a*. Polite and affable	93·5	92	78·5	66·5	13	63	53·5	55	75
b. Insolent and rude	1	·5	17	5	..	..	24	11·5	8
c. Indifferent in manner	5	7·5	8	24	1	37	21·5	36	17
29. Inclined to show temper on occasions	43·5	12·5	62	35·5	1	14·5	76	48·5	41
30*a*. Ringleader and involved in trouble and scrapes.	12·5	3	54	19	1	2	45·5	23	22
b. Belonging to well behaved and law abiding.	83·5	94·5	42·5	55	11	39	34·5	35	59·5
c. Merely apathetic	5	4	8	26	2	65·5	19	47·5	20

* Owing to the smallness of the S.I.E. group, the incidence of qualities in this group has not been turned into percentage form, though percentages have been calculated for subsequent tables.

2. *Way of Working* (*Tables III* (*a*) *and* (*b*)).

The qualities have been roughly divided into those of Application and Attention, and those of Lack of Application and Distraction.

At a glance it may be seen that both Secondary Function and Activity are of paramount importance in determining attention and application, S.F. being more particularly connected with the former, Activity with the latter. P.F. is clearly connected with distraction in the first place, with lack of application in the second place; in respect of the latter, Inactivity seems the main determinant, though its influence on the qualities of distraction is slight and less straightforward. On balance, Emotionality has a neutral influence.

What is the connection between S.F., as postulated, and the qualities found correlated with it here? The S.F. temperament types, once they are set on a task, attend easily. Their conscious field is narrow but deep. The background of integrated motives, present in Secondary form—such as the importance of doing well at school with a view to a future career, the duty to observe the rules and regulations of the class, the moral obligation of applying oneself—continually influence behaviour.

In addition to this, interest is easily sustained, not merely through its own inertia but because to the S.F. child a subject is generally not merely some abstract knowledge one is compelled to learn. It tends to be seen in relation to wider issues; its meaning links up with other bits of knowledge and information, and its implications and consequences are thus much more readily understood and grasped. Consequently, the threshold for stimuli not immediately connected with the task in hand is very high. This can conceivably lead—when Secondary Function is too predominant—to a too restricted conscious field, where it is difficult to arouse any attention at all.

The P.F. group, on the other hand, owing to weakness of the Secondary process, display an extensive, but very shallow, conscious field, leading to a splintered attention and a mental life somewhat deficient in inner integration. They react immediately and readily to any stimulus or to the impulse of the moment, without reference to a background of motives, or secondary considerations. This is the explanation of their unsatisfactory way of working, as illustrated by Table III. It is difficult to catch their interest for any length of time, unless the significant implications of subject, lesson, or task can be brought home. If the child can be made to live the lesson, taking an active part in it, or see the subject in relation to some of his usual activities, Secondary attention can be sustained. The lack of integration from within must be compensated for by creating outer significance, integration with the more immediate meaning

TABLE III (*a*).*

Qualities of Attention and Application.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
1*a*	Work regularly with application and zest.	79	−16·4	+62·6	60·6	−34·8	+25·8	54·2	−41·1	+13·1 (3)
2*a*	Usually attentive	94	−22·4	+71·6	66·9	−49	+17·9	58·4	−57·5	+ ·9
14*b*	Calm and quiet	72·2	−19·1	+53·1	55·9	−35·5	+20·4	42	−50	− 8
15*a*	Get down smartly to set classwork .	69·2	−41·1	+28·1	83·2	−27·1	+56·1	55·6	−54·8	+ ·8
16*b*	Try to fight through with determination.	41·9	−27·1	+14·8	63·1	− 5·9	+57·2	29·9	−39·1	− 9·2 (2)

TABLE III (*b*).

Qualities of Distraction and Lack of Application.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
1*b*	Work with alternate periods of laziness, etc.	14·2	−70·8	−56·6	36·5	−46·9	−10·4 (2·6)	36·9	−48	−11·1 (3)
c	Lazy	6·6	−13·2	− 6·6	2·6	−17·2	−14·6	8·4	−11·5	− 3·1
2*b*	Easily distracted . .	3·5	−48·4	−44·9	19·4	−32·5	−13·1 (3·6)	25	−26·9	− 1·9
c	Playful	1·2	−23	−21·8	14·4	− 9·6	+ 4·8 (1·9)	16·2	− 7·8	+ 8·4 (3)
d	Often busy with other things than lessons.	3·1	−25	−21·9	8·8	−19·4	−10·6	11·1	−15·5	− 4·4
3	Immediately stop attending at end of lesson.	6·2	−68	−61·8	33·1	−40·9	− 7·8 (2)	35·4	−38·6	− 3·2
14*a*	Restless and inclined to fidget.	6·4	−68	−61·6	42·4	−32	+10·4 (2·5)	46	−29	+ 17
c	Lifeless and inert . .	21·9	−12	+ 9·9 (3·3)	·4	−33·5	−33·1	12	−22	− 10 (3·5)
15*b*	Inclined to dawdle and waste time.	27·5	−58·2	−30·7	16·2	−69·5	−53·3	41·7	−44	− 2·3
16*a*	Inclined to give up . .	29·4	−52	−22·6	14·8	−66·6	−51·8	40	−41·4	− 1·4
c	Ask for help . . .	28·4	−21·9	+ 6·5 (2)	23·1	−27·1	− 4 (1)	29·9	−20·4	+ 9·5 (2·8)

* The percentage incidence of qualities in the negative grouping of each variable (primary, inactive, non-emotional) has been marked negative in this and the following tables.

and action-complex of the individual. If such interest is not aroused the child will exercise its natural mobility on anything and everything the moment presents: scribble, play, carve the desk, or be generally restless and fidgety. The lesson over, attention is with the greatest of ease transferred to something else; all that went on a few minutes previously fades from consciousness. Alternations in application are frequent. Suppose that by pure chance or the nature of the lesson attention is caught. The child will work with might for a while. Something else gets into the way a few hours later, or the lesson presents too many abstractions, and distraction takes the place of work. There is no "braking," regulating background, as with the Secondary child, which keeps up a fairly even performance. Yet laziness pure and simple, or lifelessness and inertia, are not causally determined by Function.

The function of Activity is to provide the essential driving force for all these Application reactions. Function differences merely determine the pattern, which the conative force will assume. Activity will display the one pattern we have described in the S.F. group, the other pattern in the P.F. group. The S.I. group, once they have started on a task—stimulability will of course be severely restricted—can give the impression of attending and trying when up against a difficulty, while in fact they are but dreamily inert. Stimulability is not lacking in the Primary, but when absence of S.F. is accompanied by lack of Activity, a mere restlessness and inclination to fidget is produced. Hence Inactivity tends to manifest itself as Lifelessness and Inertia among the S.F. (+ 9·9 per cent., 3·3 × S.D.); Distractibility (− 44·9 per cent.) or mere Restlessness (− 61 per cent.) among the P.F. In so far as attention, distraction, calmness, playfulness, restlessness are patterns of reactions, they are determined by the Function variable; Determination and settling to work or their opposites, laziness and dawdling, are more directly the expression of the Activity variable.

An examination of the p.i. differences in respect of 15*a* and 16*b* (Table III (*a*)) shows, however, + 28·1 and + 14·8 per cent. in favour of the S.F. Our procedure has been to equalise the number of Actives and Inactives in the P.F. and S.F. groups. Consequently, if getting down smartly to set class-work and trying to fight through with determination are functions of Activity, there should be no p.i. difference at all between the two Function classes. What is the nature of this overlap? Given a fairly low Activity level in a S.F. case, this Activity will be conserved in a narrow channel and saved from wastage through distraction or splintered attention. Hence it will be able to effect something, be it only the carrying out of a few lowly motives, or the adequate performing of a routine task. In a P.F. case of equal Active strength, whatever

energy there is will be dissipated, diffused through the scattered channels of the type. Restlessness there will be in plenty, but willed acts of any importance few in number. In this case, the pattern determining the mode of operation of the Activity variable is actually responsible for obscuring its manifestation entirely. The Secondary pattern, on the other hand, can actually emphasise, or in any case conserve it.

Hence the overlap is not a real overlap at all. As one cannot measure Activity operating *in vacuo*, it must be measured through some mechanism or function which modifies it in accordance with its own nature. When a weak Activity *can* still be detected when operating through a Secondary Functioning mechanism, it *cannot* when operating through a Primary one. The correlation we have actually observed is a measure of this, and is consistent with both the nature of Activity and of Function. It detracts in no way from the essential unity and distinctness of these variables.

We shall come across further examples of this overlap in the course of our analysis of the function of the variables. The same process will be found to have taken place throughout. There is a dynamic relationship between them, whereby their function is consistently affected. Many qualities or behaviour patterns can only be fully understood in terms of this interrelation.

Table III gives some indication of the adaptive value of Activity. It is negatively related to nearly all qualities of distraction and lack of application. The Primary Actives tend to display less and less the more extreme features of the Primary pattern as Activity increases. The flow of energy and persistence which they possess, will help them to counteract the splintering of attention. Impelled by the urge for action, they may get sufficiently far with a task to reinforce their initial interest, so that a distraction is less likely to be effective. The action itself becomes the motive of the moment. Integration will therefore be more likely to take place, and some measure of S.F. will be able to assert itself. Similarly, a deficient stimulability due to excessive braking and consequent narrowing of interest will be counteracted by the ampler opportunity and necessity of reaction which will follow on the pursuit of some compelling motive.

We can make the generalisation, to be confirmed by subsequent analysis, that Activity determines socially valuable behaviour qualities. No ethical principles are involved in the application of the terms "valuable" or "less valuable." They merely indicate the adequacy of the adaptation made to environment. Where the first overlap we discussed was indicative of the influence of Function on Activity, this second one indicates the reciprocal influence of Activity on the Function mechanism.

Turning now to a more detailed examination of the influence of Emotionality we find a few significant relationships.

At this stage it is idle attempting to define Emotionality more closely than we have already done. A detailed interpretation must therefore be postponed. We venture the suggestion that the existence of motives of an emotional kind will both increase the range of stimulability and reinforce overt action, causing reactions to take place which otherwise might not have occurred; at the same time feeling tone may increase the strength of reactions, be they adapted or non-adapted. Thus Emotionality increases application (+13·1 per cent., 3 × S.D.), but also increases restlessness (+17 per cent.), counteracts lifelessness (−10 per cent., 3·5 × S.D.), but increases playfulness (+8·4 per cent., 3 × S.D.).

If reference is now made to Table II, which gives the *actual* p.i. of all qualities in the eight type groups, it will be seen that those relationships which would be expected on the basis of the deductions we have made, do in fact occur. Maximal scores are obtained by the two Secondary Active types for application (95 and 91 per cent. − p.i. whole group 49·5 per cent.), attention (98 and 97 − 57 per cent.), calmness (86·5 and 93·5 − 48·5 per cent.). (The first figure refers to the S.A.E., the second to the S.A.N., the third to the p.i. for the whole group of 645 cases.* In future the last figure will always refer to this p.i. of a quality in the whole population.) The influence of Emotionality is clearly noticeable. Restlessness reaches its peak in the P.A.E. (91 − p.i. pop. 39 per cent.). It is a P.F. pattern quality, but we have seen that both Activity and Emotionality can emphasise it. In the two Primary Active types, all qualities of distraction occur above average; the genuine Activity qualities, however, likewise (68 and 74 − 60 per cent.), though much less so than in the S.A. (94 and 97 − 60 per cent.). The Primary Inactives far exceed the Primary Actives as regards distractability (P.I.E., 60 per cent.; P.I.N., 60 per cent.; p.i. pop. 27 per cent.). The difference between the two Secondary Inactive and Primary Inactive types in respect of application is notable (79 and 51 per cent., 8 and 1 − 49·5 per cent.). On the other hand, lifelessness and inertia are most frequent among the secondary (29 and 57 per cent., 17·5 and 30·5 − 12·5 per cent.). The maximum for almost every adverse quality (dawdling 95 − 38·5 per cent.) is found in the P.I.N. group, which lacks the Active urge, the integrative and conservative power of S.F. and the reinforcing function of Emotionality. In spite of the favourable p.i. of attention among the Secondary Inactives as compared with the Primary Inactives (93 and 88 per cent., 5·5 and 9·5 − 57 per cent.), determination (7 and 10 − 42 per cent.), and readiness to act (43 and 43 − 60 per cent.) are found to be largely absent.

* This figure is not an average of the p.i.'s for the eight sub-groups, but the actual p.i. of the quality in a group of 645 taken as a whole; *i.e.* the p.i. for the whole population.

TABLE IV.

Qualities affecting School Performance.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
9*a*	Accurate (punctual at school, etc.)	65·5	– 34·4	+ 31·1	76·5	– 23·4	+ 53·1	49	– 50·9	– 1·9
	Inaccurate	30·6	– 65·4	– 34·8	23·2	– 73	– 49·8	46·8	– 49·1	– 2·3
10*a*	Attempt to grasp a problem and form opinion.	46·4	– 36·6	+ 9·8 (2½)	65·2	– 17·8	+ 47·4	44·6	– 38·4	+ 6·2 (1·6)
b	Accepts and learns by heart what is taught.	52·8	– 63	– 10·2 (2·5)	34·4	– 81·4	– 47	54·9	– 60·9	– 6 (1·5)
11*a*	Remembers what is learned clearly.	51·5	– 34·9	+ 16·6 (4·4)	73·9	– 12·5	+ 61·4	44·4	– 42	+ 2·4
b	Remembers inaccurately and in muddled fashion.	47·5	– 64·3	– 16·8 (4·3)	25	– 86·8	– 61·8	54·8	– 57	– 2·2
12*a*	Quick and ready in answering .	36·4	– 44·3	– 7·9 (2)	63·9	– 16·9	+ 47	51·1	– 29·5	+ 21·6
	Slow in answering . . .	62·6	– 54	+ 8·6 (2)	34·4	– 82·5	– 48·1	47	– 70	– 23

3. *Qualities affecting School Performance.*

Questions 9, 10, 11, Table IV, illustrate the relative importance of the variables in determining behaviour leading to success in school or conducive to failure. The figures indicate:

1. That Emotionality plays no determining part.

2. That Activity is most directly responsible for the production of these qualities (+54 per cent., 16 × S.D.).

3. That Secondary Function is involved to a lesser, but yet quite significant extent.

We shall deal with each in turn.

1. It is very likely that an excessive Emotionality, or the existence of affects and complexes, should disturb efficiency. On the other hand, a corresponding lack of it, with its attendant indifference, will similarly militate against full use being made of potentialities. One may be inaccurate, either because one is Emotional, or because one is Non-Emotional; but the positive behaviour pattern we call accuracy cannot be created by the Emotionality variable; which is what the p.i. difference indicates.

2. If Activity is manifested by a readiness to act upon some motive presentation, not merely impulsively, but with the determination to overcome obstacles until the motive is satisfied, what is then the genetic connection between that force and such behaviour patterns as clarity of

memory, accuracy, attempting to grasp a problem, etc.? It must not be forgotten that again we are not dealing with an Activity operating *in vacuo*. Function is held constant; it has not been eliminated and is assumed to be at neutral strength, with neither Primary Function nor Secondary Function predominating. This p.i. difference therefore signifies that with Activity this neutral Function ratio will produce these qualities, with Inactivity it will not. The statement that behaviour qualities leading to success in school are determined by Activity is therefore subject to this qualification.

3. When we come to the Function variable we would expect S.F. to be far more important in respect of the qualities under discussion. Accuracy demands attention to detail which should be favoured by the type of response we get from S.F. The p.i. difference is +31 per cent. The same applies to clarity of Memory (+16·6 per cent., 4·4 × S.D.). The contributory effect of S.F. is least in attempting to grasp a problem and form own opinion (+9·8 per cent., 2·5 × S.D.), where the connection with the Secondary mechanism and its peculiar advantages is least obvious and least direct.

Partly the average p.i. difference (+19·2 per cent.) * is therefore due to the more favourable connection between S.F. and the pattern of the reaction, partly it is due to the better conservation of the Activity drive in a predominantly S.F. mechanism, as was explained in the previous section.

The incidence of these qualities affords further illustration of the adaptive value of Activity. Secondary Function does not in all its phases facilitate the appearance of accuracy, clear memory, and profoundness of apprehension. When it is too dominating and strong the reaction pattern begins to display its adverse qualities: undue braking, lack of stimulability, inertia, all of which are antagonistic to effectiveness.

Reference to Table II, question 11*a*, shows 85·5 and 90 per cent. for the S.A.E. and S.A.N. types respectively, 14 and 16·5 per cent. for S.I.E. and S.I.N. types respectively. In spite of the general adverseness of the Primary reaction pattern—it has, of course, its specific positive good points, for these qualities, such as a ready stimulability and wide range of Primary attention—we find 70 and 53 per cent. for the P.A.E. and P.A.N. types respectively, 8 and 11·5 per cent. for the P.I.E. and P.I.N. types respectively. The p.i. for the whole population is 53 per cent.

Again, therefore, we find that the positive aspect of the Activity variable always operates in the direction of valuable behaviour qualities. It counteracts the extreme features of either aspect of the other variables causing them to operate in an optimum form from the point of view of

* Of qualities 9*a*, 10*a*, 11*a*.

social adjustment. We have added to this table the quality "Quick and ready in answering." Once more Activity is mainly causative (+47 per cent.). In so far as the answering is not foolish and thoughtless, mental alertness, ability to decide after rapid consideration of a number of possibilities and implications, accuracy and clarity of memory, ease and strength of volitional process generally, are required. In view of the "quickness" element involved it is not surprising that there is a slight p.i. difference in favour of P.F. (−7·9 per cent., 2 × S.D.).

It is especially the "readiness" element as distinct from mere "quickness" which is determined by Activity. It implies deliberateness and determination, different from the superficial, impulsive bustle and restlessness which often creates a false impression of Activity among the P.F.

To many questionnaires, teachers appended, as had been requested, explanatory notes and short personality sketches. There are some interesting remarks about "slowness" and "speed." In 18 out of 19 cases, where rapidity of answers, without any evidence of thought behind them, was noted, the child was P.F. In another 19 cases, where slowness was especially noted and qualified by such terms as "deliberate," "well thought out," "does not venture a reply or commit himself without consideration," 16 were S.F., the remainder P.F. Non-Emotional. The remark, "slow in speech and thought, very unintelligent," was applied to 16 Inactive cases, all but one P.F. On the other hand, "slow but accurate" was applied to 9 cases, all S.F., all but one Active, all but two Non-Emotional. We noted that "excellence in remembering" is mainly determined by Activity, yet also correlates positively with S.F. This correlation is partly due to the fact that there is such great variability in the memory process of the P.F. child. Out of 20 recorded cases of good retention in some subjects in which the child was particularly interested, 16 were P.F.; 6 P.F. cases, all Emotional, were stated to be determined workers if they happened to be interested in the particular task. This variability factor governs all actions of the P.F. type.

4. *General Conduct.*

Tables V *a* and *b* illustrate the incidence of general attributes of conduct in a variety of social situations.

1. Emotionality is clearly an important determinant in these qualities. First of all its dual direction must be noted. On the one hand, it is connected with such favourable qualities as "polite and affable" (+10·5 per cent., 3 × S.D.), "eagerness to correct and make good after error" (+9·9 per cent., 2·5 × S.D.). And especially "ready enthusiasm" (+34·8 per cent.); on the other hand, it stands in a consistently positive relationship to all adverse conduct qualities. Enthusiasm denotes a pleasant

TABLE V (*a*).

Socially Valuable Conduct Qualities.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
6*b*	Cautious	89	−38·1	+50·9	59·6	−67·2	− 7·6 (2)	49·7	−77·1	−27·4
13*a*	Constant in friendship .	78·3	−51·2	+27·1	69·9	−59·6	+10·3 (2·6)	61·4	−68·1	− 6·7 (1·8)
20*f*	When scolded take it with resignation.	62·5	−43·8	+18·7	61·1	−45·1	+16 (4)	38·1	−68·1	−30
21*a*	At exams. calm . .	56·4	−65·8	− 9·4 (2·5)	67·1	−55	+12·1 (3)	41·1	−81	−39·9
23*a*	Quickly enthusiastic, etc. .	21·9	−34·1	−12·2 (3·5)	39	−17	+22	50·4	− 5·6	+34·8
c	More reserved in expression of appreciation.	44·8	−19·9	+24·9	41·8	−22·9	+18·9	24·6	−40	−15·4
24*c*	After bad mistake eager to correct and make good.	49·9	−32·5	+17·4 (5)	63·4	−19	+44·4	46·1	−36·2	+ 9·9 (2·5)
28*a*	Polite and affable . .	85·4	−63·4	+22	82·6	−66·1	+16·5 (4·6)	79·6	−69·1	+10·5 (3)
30*b*	Belonging to law abiding and well behaved . .	73·8	−41·8	+32	68·9	−46·9	+22	59·9	−55·9	+ 4

TABLE V (*b*).

Socially less Valuable Conduct Qualities.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
6*a*	Impulsive . . .	11	−60·6	−49·6	40·5	−31·1	+ 9·4 (2·4)	49·1	−22·5	+26·6
13*b*	Inconstant in friendship .	5·8	−30·6	−24·8	14·4	−22	− 7·6 (2·4)	20·4	−16	+ 4·4
20*a*	When scolded inclined to cry.	20·8	−12·9	+ 7·9 (2·6)	10·6	−23	−12·4 (4)	26	− 7·6	+18·4
	When scolded inclined to become rude.	·8	− 5·4	− 4·6 (3·5)	2	− 4·1	− 2·1	4·8	− 1·4	+ 3·4 (2·5)
	When scolded inclined to sulk.	9/8	−33·6	−23·8	16·8	−26·6	− 9·8 (2·9)	25·8	−17·6	+ 8·2 (2·5)
	When scolded inclined to adopt annoying attitude.	1·6	− 3·8	− 2·2 (1·7)	2·2	− 3·1	− ·9	3·5	− 1·9	+ 1·6
21*b*	At exams. nervous . .	44·6	−34·4	+10·2 (2·7)	33·9	−45·1	−11·2 (2·8)	59·6	−19·4	+40·2
24*a*	After making a bad mistake, angry.	7·8	−13·2	− 5·4 (2)	8·4	−12·6	− 4·2 (1·7)	20·2	− ·9	+19·2
	After making a bad mistake, discouraged.	25	−16·8	+ 8·2 (2·5)	14·8	−27	−12·2 (3·6)	28·1	−13·6	+14·5 (4·5)
27	Headstrong, inclined to passive resistance.	7·9	−31·2	−23·3	17·1	−22	− 4·9	23·6	−15·5	+ 8·1 (2·5)
28*b*	Insolent and rude . .	·4	−14·4	−14 (7)	5·9	− 8·9	− 3	10·5	− 4·2	+ 6·3 (3)
29	Inclined to show temper on occasion.	19·4	−55·5	−36·1	38·4	−36·5	+ 1·9	47·1	−27·8	+19·3
30*a*	Ringleader, often in trouble and scrapes.	6·1	−35·4	−29·3	22·1	−19·4	+ 2·7	29·8	−11·8	+18

and positive feeling state about some object, person, or activity. Hence enthusiasm brings about what we have called emotional motivation. It implies increased and strengthened activity.

Similarly, where "warmness," feeling, enthusiasm is present, one is more likely to get affability than where it is not. Eagerness seems also to imply some emotional correlate. Thus we find Emotionality accelerating and strengthening adaptive action, while at the same time creating unique response qualities. Enthusiasm can be considered a true function of the positive aspect of the Emotionality variable. If one abstracted the Emotionality factor from it, the quality would vanish.

The same relationship holds between Emotionality and the less valuable conduct qualities. Some are the direct and obvious expressions of emotions, such as crying, becoming angry and discouraged, showing a temper, nervousness at examination. In others, Emotionality has a facilitating effect on pattern reactions otherwise determined, such as impulsiveness (+26·6 per cent.), being ringleader (+18 per cent.), insolence (+6·3 per cent., 3 × S.D.), inclination to passive resistance (+8·1 per cent., 2·5 × S.D.), rudeness (+3·4 per cent., 2·5 × S.D.). When a certain impulse or motive is frustrated the consequent behaviour pattern will follow certain lines to be discussed in connection with Function and Activity. At the same time such frustration engenders Emotionality in varying degrees depending on individual liability to it. This Emotionality will be discharged in a manner consequent with these patterns; not only emphasising them, but sometimes bringing them into operation, where they would have remained latent but for the Emotional tension and motivation. This discharge may be accompanied by characteristic behaviour qualities, specific to Emotionality. If an individual is impulsive, because he is Primary Functioning, he will be more often and more strongly impulsive when he is Emotional than when he is Non-Emotional, this strengthened impulsiveness possibly being accompanied by enthusiasm or anger, according to the situation.

Hence with Emotionality we can "hitch our wagon to the stars," as well as plumb abysmal depths.

2. Turning to Function, we see that S.F. is on the whole connected with adapted conduct. Exceptions are slight tendencies towards crying (+7·9 per cent., 2·6 × S.D.), discouragement (+8·2 per cent., 2·5 × S.D.), nervousness (+10·2 per cent., 2·7 × S.D.), and a deficiency in ready enthusiasm (−12·2 per cent., 3·5 × S.D.). The correlation in respect of the last quality is consistent with the Secondary pattern. Reserve in expression of appreciation (+24·9 per cent.) is the keynote. The S.F. do not give themselves so easily owing to the braking which all their reactions undergo; their feelings, even where they genuinely exist, are

toned down or not displayed so readily and thus the enthusiasm quality emerges less freely. That the Emotional ones among the S.F. should be more readily nervous than among the P.F. is due to the greater appreciation they have of the implications of their examinations, of their duties, possible result of success and failure, ultimate motives, etc. They care more in this particular situation; hence this emotional quality is more readily evoked.

The very high correlation with cautiousness (+50·9 per cent.) must also be noted. This is a pattern reaction which is a true function of the positive pole of the Function variable and characteristic in general of its way of operating. It implies the careful weighing of pros and cons which is only possible with a fair amount of S.F. Throughout there is an element of restraint in conduct favoured by S.F. Again, it follows that in extreme form this restraint and cautiousness can lead to severely restricted stimulability and apathy.

The part played by Primary Function in the production of socially less adapted behaviour qualities is very striking, and the weaknesses inherent in this mode of response emerge very clearly. Impulsiveness (−49·6 per cent.), inconstancy in friendship (−24·8 per cent.), inclination to show a temper (−36·1 per cent.), getting into trouble and scrapes (−39·3 per cent.), insolence and rudeness (−14 per cent.) are all determined by it. With S.F. cautiousness, with P.F. impulsiveness, is generally characteristic. It should also be noted that whereas the S.F. adverse conduct qualities are all of a passive kind, those of the P.F. are aggressive. Egoistic, a-social drives are the starting-point of all human nature, and satisfaction of the ego remains always an important consideration. This satisfaction becomes socially conditioned. Yet in spite of the acquired mass of social habits the P.F. child, owing to his neural organisation, often acts primitively. Rudeness, temper, impulsive action of one kind or another are primitive, aggressive reactions, evoked when a motive of the moment is frustrated. Hugo (23), discussing the same findings, says: "As regards morality, there is no reason to suppose that the P.F. child is less morally inclined, or that it is less appreciative of moral principles, than the S.F. child. But we must add to this that equal strength of (moral) impulse is not always accompanied by equal power of control over motives. In the P.F. child the whole of consciousness is occupied by motive representations of the moment; he only disposes of the data which at that moment and under those circumstances are present. In the S.F. child, however, earlier experiences are still operative. The given motive representations are therefore strengthened, braked, according to the favourable or unfavourable light thrown on them by earlier experiences and former decisions."

Thus also can we account for the prevalence of "Ringleading, always

in trouble and scrapes" among the P.F. The P.F. are usually pleasant and popular. Motivated by playing up to this popularity and aided by their impulsiveness, they undertake actions, the implication of which are not fully appreciated. Thus they tend to get more often involved in scrapes and show in this connection more undesirable qualities than the S.F. Similarly their inconstancy in friendship is not so much due to perfidy, quarrels, ill-feeling against the former friend as a tendency to react to something new, throw the whole personality into it for a while; and then, as fundamental bonds are not established, to flit as easily away again to new enthusiasms.

The impulsive conduct qualities can therefore be considered a functional aspect of the P.F. pattern. Within this pattern aggressive behaviour readily follows on the thwarting of immediate impulses. The emotional tension following on the frustration of a strong impulse is not inhibited as easily as in the S.F. group. In nine cases a special note was added to the questionniares: "Emotional, but does not display feelings readily." All were S.F. Active cases. In four P.A.E. cases special mention was made of the strength and frequency of emotional behaviour, and in the case of one P.A.N. type "Non-Emotional" was marked, but added to it was, "But displays what feelings he has." When discharged the Emotional tension will naturally reinforce the overt aggressive action. There is the slight tendency already referred to, for the tension to discharge passively in the form of discouragement and crying in the S.F. group, which is in keeping with the non-aggressive cautiousness pattern of the positive aspect of this variable.

At this stage a further relationship between Function and Emotionality must be considered. When strong S.F. is combined with strong Emotionality, the consequent excessive narrowing and deepening of the conscious field leads to the formation of intense, passionate drives, directed mainly to one or a few highly emotionally charged goals. This tends to diminish to a large extent that braking effect exerted by a system of integrated motives. The lives of such S.F. cases become like the moments of the P.F. in extenso. Aggressive reactions, temper, or headstrongness will occur, not because of a mere yielding to the motive of the moment, but because through excessive integration there are no counteracting motives. All action takes place within this one all-embracing drive, and its frustration is the frustration of all that matters. The reaction pattern displayed by such S.F. Emotional cases is phenomenally identical to, though genetically quite different from, the Primary pattern. The sum-total behaviour patterns will likewise be different; in the one case stereotyped, only called forth by situations connected with the main personality drive; in the other case varied, arising again and again with all sorts of situations.

The apparent overlap between the positive aspect of the Emotionality variable and the negative aspect of the Function variable in respect of the more aggressive conduct qualities is therefore due to:

(*a*) The more frequent evoking of the Primary pattern as a result of emotional motivation.

(*b*) The fact that in weakly P.F. cases a latent typical pattern is brought out by the emotional reinforcement.

(*c*) A number of Secondary Emotional cases display behaviour consistent with the Primary pattern, though genetically different from it.

3. Once more (Table V) the Activity variable has no adverse function in its positive form. It is positively and significantly related to all the adaptive functions of either aspect of the other two, facilitating their occurrence. Inactivity does not significantly determine or facilitate any of these adverse conduct qualities. On balance, therefore, such influence as Activity has on conduct is wholly favourable. When a difficulty crops up or an impulse is frustrated, the Active immediately ask themselves what can be done about the matter. Hence both the emotional tension, if it exists, and the original impulse will tend to be discharged, not in the form of a struggle response nor inwardly in complex formation or worry, but in the devising of some practical solution. *Mere* aggressive impulsiveness will not be favoured by the Active. Such acts are not so likely to reach a goal, or will only reach it after much waste of effort. As the Active are marked by a determination to succeed, the result of such merely aggressive behaviour will cause it to be avoided in the future. Largely by means of such a process will the Primary pattern be toned down, although the Primary Actives will always retain a dash, speed, impulsiveness behind their—nevertheless directed—actions not found with the more deliberate and cautious Secondary Actives.

Referring to Table II again, we find the following p.i. for Impulsiveness in the P.A.E., P.A.N., S.A.E., S.A.N., respectively 82, 50, 27, 3 per cent. P.i. population 37 per cent.

In question 29, "Inclined to show a temper," we get for the same types respectively 62, 35·5, 43·5, 12·5 per cent. P.i. population 41 per cent. In question 27 *a*, "Headstrong and inclined to passive resistance," 30·5, 21·5, 11·5, 5,—20 per cent. In the P.I.E. and P.I.N. groups the p.i. for the last two qualities is respectively 76 and 48·5 per cent.; 45·5 and 27·5 per cent. Interesting also are the p.i. figures for "polite and affable," 93·5, 92, 78·5, 66·5 per cent. for the S.A.E., S.A.N., P.A.E., P.A.N. respectively; 93, 63, 53·5, 55 per cent. for the S.I.E., S.I.N., P.I.E., P.I.N. respectively. "Insolence and rudeness" occur as follows: 1, ·5, 17, 5, 0, 0, 24, 36,—8 per cent. Without Activity the P.F. pattern emerges clearly. It is true that the S.I.N. are also below average for politeness and affability,

but they show a tendency towards indifference (37 – 17 per cent.), with no insolence and rudeness at all. Clearly, then, subject to the counteracting influence of Emotionality, the effect of Activity is as stated.

On the whole, we would expect the worst form of behaviour from the nervous P.I.E., to a lesser degree from the P.I.N.; of quite a different order from the S.I.E. and S.I.N. types (less aggressive, less antisocial). The S.A.N. type, though exemplary in conduct, would yet lack the benefits as well as the drawbacks of Emotionality, the tendency of S.F. towards reserve and caution not being counteracted.

This is found to be the case. The P.I.E. exceed all other types in temper (7·6 – 41 per cent.), inconstancy in friendship (37·5 – 19 per cent.), sulking (49·5 – 22·5 per cent.), anger after error (26·5 – 10 per cent.), being headstrong (45·5 – 20 per cent.), insolence (24 – 8 per cent.). The sentimental S.I.E., on the other hand, show a peak for "crying when scolded" (50 – 12·5 per cent.), nervousness at examinations (86 – 34 per cent.), discouragement (43 – 17·5 per cent.). The phlegmatic S.A.N. have maximal scores for calmness at examinations (87 – 66·5 per cent.), reserve (76·5 – 34·5 per cent.), politeness (92 – 75 per cent.), good behaviour (94·5 – 59·5 per cent.), constancy in friendship (83 – 64·5 per cent.), while only the S.I.N. (apathetic), owing to their lack of Activity, can outdo them in caution (97 and 100 – 61·5 per cent.). Emotionality has altered this pattern in the passionate S.A.E. towards greater enthusiasm (56·5 and 10 – 31·5 per cent.) and impulsiveness (27 and 3 – 37 per cent.), on the one hand, and more nervousness (56·5 and 13·5 – 44 per cent.), crying (20 and 3 – 12·5 per cent.), temper (43·5 and 12·5 – 41 per cent.), passive resistance (11·5 and 5 – 20 per cent.), on the other hand. There is a peak for ringleading (54 – 22 per cent.) in the choleric P.A.E. To be responsible for all kinds of petty crimes and unpleasantness is one thing; to be sufficiently popular and daring to lead the gang demands more sterling qualities, derived from Activity, and it is probably in this respect that the P.A.E. excel. The p.i. for enthusiasm reaches a maximum with them (80 – 31·5 per cent.), while they are just above the average in respect of politeness (78·5 – 75 per cent.) and eagerness to make good (57·5 – 47 per cent.). A noteworthy feature in the P.A.N. type is the tendency towards indifference, as compared with reserve and caution in the S.A.N. (23*b*: 13·5 and 47·5 – 33·5 per cent.; 28*c*: 7·5 and 24 – 17 per cent.).

The qualitative material, derived from notes appended by teachers, is in close agreement with our findings in respect of conduct.

If we examine references to the more positive, striking qualities of Temperament and Personality, we find the honours on the side of the Primary Functioning child as being "popular, smart pupil, original, vivacious, alert, bright and optimistic, endowed with a sense of humour,

good natured, pleasant and frank, honest, likeable, happy, independent, quick-witted and observant, energetic, self-confident, practical and capable, sensible and self-willed." Out of the 71 times on which one or other of these epithets was recorded, it was applied 34 times to the Choleric (P.A.E.), 11 times to the Passionate (S.A.E.), 19 times to the Phlegmatic (S.A.N.). Only 5 times was it applied to an Inactive type.

The Primary Active child enjoys an all-round popularity. Yet on the other side of the picture we find that "petulant, affected, unpopular, bully, effeminate, weak, quarrelsome, nasty nature, uncouth, insolent, careless, untidy," are recorded for 32 cases, of which 26 are Primary, 12 of these Inactive.

Only 3 cases of delinquency are specially mentioned among the Secondary types (excluding, of course, the Industrial School group). Two of these were sex offences, the third a case of theft with skilful lying accompanying it.

Among the Primary types truancy is the most common complaint, very naturally so owing to restlessness, desire for stimulation, and the difficulty experienced by this type of child in giving Secondary Attention; six Primary cases were stated to be habitual truants. This type of child will naturally chafe at the cramping school routine, hanker for the freedom of the street or country, and will be induced to escape and seek this freedom, to evade the continual punishment which its Temperament earns for it.

Only one case was noted among the Secondary, displaying a reprehensible trait (apart from actual delinquency)—namely, "playing shady games."

Among the Primary such traits are rife. "Cribbing," cowardliness, dirty sport, slyness, cringing, telling lies, stealing, mischievousness, running away from home, sneaking, telling tales, quarrelsomeness, bullying, two-facedness, surreptitious behaviour; all these occur among the Primary, none are mentioned with the Secondary. Yet with it all, some of these delinquent cases are stated to be "likeable."

In our group of 73 Industrial School boys, all but a few delinquent, *no fewer than* 55, *or* 75 *per cent., are Primary Functioning.* Transferring the doubtfully Active Cases to the Inactive side, *we find* 42 *of these* 55, *or* 76 *per cent., Inactive,* while 28 of the 55, or 51 per cent., are Emotional. These figures are striking, and agree with Hugo's findings that delinquency, or breaking of the peace, purposely upsetting the order of the classroom, reprehensible character traits, go with Primary Function and Inactivity combined, in a maximal degree if strong Emotionality is added.

A number of elucidating remarks were also added to the question on "Ringleaders, etc." In 22 cases it was specifically noted that there was no *leading*, merely naughtiness and trouble. These were all Primary cases,

of which 8 Inactive Emotional, 5 Inactive Non-Emotional; of 13 cases it was stated that they were leaders, without being lawbreakers. Six of these were Secondary, and 4 of these again S.A.E.

Regarding Politeness, in 50 cases "affable" was struck out; 31 of these were Secondary, and of these again 28 Phlegmatic. Where the absence of "affable" amounts to "reserved politeness" in the Secondary, it tends to "offhandness and brusqueness" in the Primary. The observation was also made that Primary children are sometimes polite towards teachers, rude, quarrelsome, indifferent to inferiors or equals. On the whole, in spite of some of these failings, the Primary, especially the Active, are extremely popular, likeable, and cheerful.

Finally, some Emotionality seems to be essential for the formation of friendships. In 15 cases "no friends" or "no capacity for friendships" was remarked. All but one were Non-Emotional; 11 were Inactive, Function making no difference.

TABLE VI.

Determination of Mood.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
7*b*	Depressed . . .	11·5	− 6·2	+ 5·3 (2)	4	− 13·8	− 9·8 (2·6)	7·2	− 10·5	− 3·3 (1·4)
d	Always even of mood .	46·6	− 10·8	+ 35·8	24·4	− 33·3	− 8·9 (2·4)	19·5	− 38·9	− 19·4
8*c*	Good humoured . .	67·4	− 55·6	+ 11·8 (3)	71·9	− 51	+ 20·9 (5·2)	56·4	− 66·7	− 10·3 (2·7)
d	Unable to be angered .	19·4	− 4·1	+ 15·3	4·6	− 18·9	− 14·3 (5·3)	8·2	− 15·2	− 7 (3)
22*a*	Depressed and pessimistic .	41	− 27·8	+ 13·3	17·8	− 51	− 33·2 (9)	31	− 37·8	− 6·8 (1·8)
7*a*	Cheerful	33·6	− 49·1	− 15·5	56·5	− 26·2	+ 30·3	45·4	− 37·4	+ 8 (2)
c	Alternately cheerful and depressed.	11·7	− 39	− 27·3	19·5	− 31·4	− 11·9	31	− 22·4	+ 8·6 (2·5)
8*a*	Irritable	3·4	− 19	− 15·6	9·3	− 13·1	− 3·8 (1·5)	13·8	− 8·6	+ 5·2 (2)
b	Quickly offended . .	10·5	− 25·6	− 15·1	16	− 20·1	− 4·1 (1·3)	23·8	− 12·4	+ 11·4 (3·8)
22*b*	Bright and optimistic .	55·1	− 69	− 13·9 (3·7)	78·6	− 45·6	+ 33	65·6	− 58·5	+ 7·1 (2)

5. *Determination of Mood.*

By arranging the qualities into two sub-groups : (*a*) even and subdued behaviour, (*b*) elated, aggressive, variable behaviour, certain broad differences are made to appear at once.

1. Activity goes positively with Good Humour (+ 20·9 per cent. 5·2 × S.D.), Cheerfulness (+ 30·3 per cent.), and Optimism and Brightness,

(+33 per cent.) to a greater extent than the other variables. It stands in a negative relationship to all other mood qualities.

2. Cheerfulness is characteristic of the Primary form of the Function variable (−15·5 per cent.), Good Humour of the Secondary form (+11·8 per cent.). The P.F. alternate in mood (−27·3 per cent.), while the S.F. are above everything even (+35·8 per cent.), and as often depressed and unable to be angered as the P.F. are irritable and quick to take offence.

3. Throughout Emotionality opposes all even and depressed behaviour, being entirely antagonistic to S.F. in its action.

We shall discuss each in turn.

1. As the Active go out to meet their difficulties and adapt to circumstances, it is not surprising to find them generally cheerful and optimistic. In accordance with the qualities we have found associated with Activity, they must possess a vigorous metabolism and overflowing energy. As there is no blocking of the Emotional discharge complexes do not form readily, and disappointments are quickly forgotten in the active pursuit of a solution. Zest for life, a feeling of well-being—*joie de vivre* is the result. This general euphoria can be considered a true function of Activity, as it is independent of Functional pattern and independent of Emotional configuration, though it contains, of course, a pleasant feeling tone. The term "Brightness and Optimism" would describe it best, and it is significant that in respect of this quality we find the largest p.i. difference in favour of Activity (+33 per cent., 14 × S.D.). The next nearest are Cheerfulness (+30·3 per cent., 8 × S.D.) and Good Humour (+20·9 per cent., 5·2 × S.D.).

2. With Cheerfulness and Good Humour the effects of the Functional effector patterns on this general euphoria become once more clearly apparent. Brightness and Optimism occur somewhat more frequently in the P.F. group (−13·9 per cent., 3·7 × S.D.). The S.F. are not demonstrative, and where the pattern is very pronounced the euphoria, although existing, may not be so readily expressed. In many cases it cannot be superficially detected. Function differences do not affect Brightness as such. It is diffuse and undifferentiated. Good Humour, on the other hand, is the expression of the general euphoria through a S.F. system, Cheerfulness its expression through a P.F. system. The responses of the S.F.—their manner, voice, gestures, laughter, etc.—are slightly less immediate, less expressive, less free from past and future reference than those of the P.F. The latter are more inclined to bubble over with elation, and their every act is coloured by this feeling. Nevertheless, Activity remains the chief determinant. It alone will ensure the relative permanence of these qualities, which is an essential aspect of the behaviour gestalten they designate.

The differences between the Function patterns are of much greater

importance in the determination of the typical mood qualities of evenness, placidity, depression; and variability, moodiness, irritability. If the S.F. person experiences some set-back he may reflect that he has had a fairly long run of luck, that to-morrow is another day, and that he always pulled through in the past. A piece of good luck is similarly received with reference to past and future. Hence there are no sudden and marked fluctuations in the prevailing mood, which tends to an even, placid level. When a motive is frustrated in the P.F. that is all that matters at the time. Compensatory considerations are unable to assert themselves, and no braking of the emotion aroused occurs. They are readily angry, depressed or elated in turn, the prevailing mood being one of frequent fluctuation. It is the familiar result of reaction to the stimulus, rather than an integrated response to a complete situation.

3. Emotionality plays by no means as important a part as is commonly accepted. Throughout it is opposed to the S.F. pattern, especially to its evenness ($-19{\cdot}4$ per cent.) and placidity (-7 per cent., $3 \times$ S.D.); but although it reveals a constant positive relationship with the assertive qualities, this relationship is nowhere very considerable. The difference between the Emotional and the Non-Emotional is that in the latter pleasant or unpleasant feeling tone do not occur so intensely or in such a striking manner; that patterns such as anger and grief, nervousness and enthusiasm are not so readily formed; that on the whole behaviour is not emotionally determined.

Undoubtedly these assertive mood qualities involve some feeling tone, but they can occur just as distinctly, though not as intensely, with the feeling tone at the disposal of the Non-Emotional. The quality which approximates most to the more specific emotional pattern is "quickly offended," and it is in respect of this quality that the effect of Emotionality is most evident ($+11{\cdot}4$ per cent., $3{\cdot}8 \times$ S.D.).

The blocking of some impulse may arouse an intense unpleasant feeling tone in an Emotional P.F. case, a mild one in a Non-Emotional P.F. case. The oscillation in the latter case will be much less marked than in the former; but the alternation pattern as such is not altered, and hence Function remains the determining factor.

In respect of Mood, Emotionality is therefore mainly operative in emphasising the Function patterns. The interaction between Emotionality and Function, already discussed in connection with conduct, also takes place here and is responsible for the observed overlap. (*a*) The existence of motives of an Emotional value will tend to increase unevenness of mood in the Emotional. (*b*) A weak and latent P.F. mood pattern becomes evident through the discharge of emotional tension. (*c*) Certain strongly Emotional, strongly S.F. cases can display a mood pattern

superficially akin to that of the P.F. The significant relationship between evenness of mood and Non-Emotionality (– 19·4 per cent.) can be accounted for on somewhat similar grounds.

In accordance with this analysis we find Evenness of Mood maximally in the S.I.N. (67 per cent.), closely followed by the S.A.N. (54 per cent.). Owing to the presence of Emotionality, it is not a marked quality of the S.A.E. (30·5 – 28·5 per cent.).

Alternation reaches a peak in the Nervous P.I.E. (51·5 – 23·5 per cent.). Owing to the presence of Activity it is greatly diminished in the P.A.E. (36 per cent.), while in the S.A.N. it is practically absent (3·5 per cent.).

Depression reaches its peak in the S.I.N. (73·5 – 27·5 per cent.). Emotionality causes it to be less prominent in the S.I.E. (57 per cent.), still less in the P.I.E. (33·5 per cent.), and minimally in the Active types. Irritability, on the other hand, occurs maximally in the P.I.E. (28 – 10·5 per cent.), still to a fair extent in the P.A.E. (18 per cent.), but not at all in the S.A.N. (·5 per cent.). In readiness to take offence the S.A.E. differ considerably from the S.A.N. (19, 5 – 18·5 per cent.), though the maximum is once more reached in the P.I.E. (38·5 per cent.), where Emotionality, P.F., and Inactivity all favour its appearance.

Brightness and Optimism is common property of the Active types, the slight differences being consistent with the incidence of Emotionality. The quality is least prominent in the S.I.N. (22·5 – 67·5 per cent.), the P.I.E. group possessing it in a higher degree than the other Inactive types, owing to its Emotionality and Function mechanism (58·5 per cent.).

On the other hand, there is a minimum p.i. in this group for Good Humour (36 – 64 per cent.), which is at its maximum in the S.A.N. (78·5 per cent.). The S.A.N., however, are deficient in cheerfulness (42 – 45·5 per cent.), which is at its peak in the P.A.E. (63 per cent.) and S.A.E. (61·5 per cent.).

The worst Temperament type for moodiness is therefore the P.I.E., for depression the S.I.N.; the S.A.E. are the most virile and attractive, combining Cheerfulness and Good Humour with evenness and the occasional show of Temper. The S.A.N. tend to be too colourless, the P.A.E. too colourful, the S.A.E. steering an attractive and well-balanced course between the two.

6. *Qualities of General Indifference.*

General Indifference in manner, lack of interest in things, indifference after making a bad error, accompany the negative aspects of all three variables, though they are mainly determined by Inactivity and Non-Emotionality (– 26·9 per cent., 7·5 × S.D. and – 27·9 per cent., 8·5 × S.D.).

The part played by each of these two variables is quite distinct. Indifference can imply two things: (*a*) that nothing is done about a thing; (*b*) that there is nothing to do anything about. The first occurs with lack of Activity, the second with lack of Emotionality. Both give a final general impression of Indifference, as reflected in the correlations; yet the distinction is an important one. In respect of Enthusiasm the Actives surpass the Inactives by 41 per cent. We have already found that Enthusiasm is a function of Emotionality; it also implies doing something about a thing. Where there is a very weak Active impulse, motives will have to be tremendously strong to produce any reaction at all. The Inactives, though they may experience the feeling and give some sign of enthusiasm, yet may not have the will or energy to follow it up. Hence they are frequently considered devoid of it. One often finds people losing chances of advancement, of following up an alluring possibility which presents itself, not because they have failed to see or appreciate these, but because they lacked sufficient "go," or initiative, to take the trouble.

TABLE VII.

General Indifference.

No. of question.	Qualities.	Per cent. Secondary.	Per cent. Primary.	Difference.	Per cent. Active.	Per cent. Inactive.	Difference.	Per cent. Emotional.	Per cent. Non-Emotional.	Difference.
23*b*	Indifferent. No enthusiasm . .	34	– 45	– 11 (3)	19	– 60	– 41	23·5	– 55·5	– 32
28*b*	Indifferent in manner . . .	14·1	– 22·4	– 8·3 (2·8)	11·1	– 25·4	– 14·3	10·4	– 26·1	– 15·7
24*a*	Indifferent after making bad error .	21·8	– 39·2	– 17·4 (5)	17·2	– 43·8	– 26·6	10·8	– 50·2	39·4
30*c*	Apathetic as regards law and order .	22·1	– 25·1	– 3	10·8	– 36·5	– 25·7	11·5	– 35·8	– 24·3
14*c*	Lifeless and inert	21·9	– 12	+ 9·9 (3·4)	·4	– 33·5	– 33·1	12	– 22	– 10

In the case of Non-Emotionality leading to Indifference, there are not sufficient motives upon which to act. If one feels nothing about an event, situation, etc., though one could react to it, one lacks the desire. Hence the maximum p.i. difference in respect of indifference after making a bad error occurs in the Non-Emotional group (– 39·4 per cent.).

With the strongly Non-Emotional one can expect *Indifference towards specific things*, accompanied by ceaseless and determined labour on perhaps a few set or routine tasks, on which such feelings as they have are

concentrated; with the Inactive *Indifference generally*. This analysis shows that the quality "Indifference" covers genetically different responses, and consequently that the overlap between Activity and Emotionality in producing it is apparent, not real.

Indifference is less frequent in the S.F. group than in the P.F. group. We are dealing here with another instance of the conservative effect of S.F. on Activity. The Secondary Inactives are better able to turn such activity as they possess to an effective use than the Primary Inactives, who, owing to distraction and lack of secondary reinforcement, do not persist for any length of time at the same task and who are thus unable to effect a willed act of any importance. The greater or lesser indifference remains therefore a function of the Activity variable, Function merely playing a facilitating or inhibiting part. On its own account, the influence of Function is neutral. The greater stimulability of the P.F. is antagonistic to Indifference, but this is offset by the greater reinforcement of motive, owing to perseveration and integration, counteracting Indifference in the S.F.

We would expect the maximum incidence of these Indifference qualities in the S.I.N. and P.I.N. types. For "No Enthusiasm" the p.i. in these two groups is respectively 73·5 and 87·5 per cent.; p.i. population 33·5 per cent. It is rather striking that "apathy towards law and order" occurs maximally in the S.I.N. (65·5 – 20 per cent.), called the Apathetic type by Heymans. Lifelessness and Inertia reach here also a peak (57 – 12·5 per cent.). This reveals the intense lack of stimulability in the S.I.N. types, to which we have frequently referred. The presence of Emotionality in the S.I.E. group acts in a compensatory manner (57 and 28 per cent.), while in spite of their maximal lack of enthusiasm (87·5 – 33·5 per cent.) the P.I.N., owing to their more lively primary attention, are also less apathetic (47·5 per cent.) and lifeless (30·5 per cent.). The P.A.N. are, of the Active types, most subject to Indifference, exceeding the P.I.E. in this respect in all qualities but Lifelessness. This is due mainly to the absence of Emotionality, partly to the lesser effectiveness of their Active drive. The S.A.N. approximate most to them; we have seen elsewhere that where Enthusiasm yields to Indifference in the P.A.N. group, it becomes Reserve in the S.A.N. The S.F. mechanism proves of distinct advantage here. The two Active Emotional types are minimally subject to Indifference.

In 36 cases, to the question "occupied after school, etc.," "No Interests" was added, or phrases such as "sleeps," "star-gazing," "loafs about," "hangs about," "messes about," etc. Of these, only 9 are Active (1 S.F.A.), 27 Inactive (1 S.I.N., 11 P.I.E., 15 P.I.N.). Of the 36, 14 are Emotional. This corresponds fairly well to the above findings.

7. *Summary of Function of Variables.*

1. *Secondary—Primary Function.*—All behaviour patterns are largely determined and always influenced by the Function mechanisms. *Secondary Function determines:* (1) *Steadiness of attention and calmness.* (2) *Socially valuable behaviour qualities of a restrained sort; those less valuable qualities determined by it are of a passive kind.* (3) *Evenness of Mood and Good Humour with a tendency to depression and extreme placidity.*

The behaviour pattern is the result of the perseverative effect of all past experiences. Hence there is a braking effect on immediate effector, as well as on receptor activity leading to a deep, though narrow, conscious field. Reactions are made against a background of motives, past and future actions, social habits, principles; to the situation rather than to the stimulus. Evenness is its keynote. Secondary Function facilitates zeal, application to work, and those qualities leading to a general effectiveness. It is less frequently associated with Indifference than the Primary aspect of the variable. The facilitative influence is partly due to its inherent tendencies, partly to the conservative effect of the mechanism on Activity.

It exerts a braking influence on direct Emotional expression and therefore stands in a slightly negative relationship to the function of Emotionality.

Primary Function determines: (1) *Primary attention, distraction, and restlessness.* (2) *Socially less valuable behaviour qualities of an assertive and aggressive type. Impulsiveness, by no means always an adverse quality, is its chief characteristic in this connection.* (3) *Variability of Mood and Cheerfulness, with a tendency to irritability and readiness to take offence.*

This behaviour pattern is the result of a comparative lack of perseveration. The absence of a brake on responses leads to a shallow, extensive, conscious field, with a low threshold for any stimulation and a splintered attention. Reactions are made to the primary stimulus and the motive of the moment, not integrated with any other motives and the socially conditioned background. Consequently, actions are often contradictory and variability is the chief attribute of the type. Primary Function facilitates quickness and readiness, but on the whole is at a disadvantage in those qualities producing general effectiveness. It is more often than S.F. associated with General Indifference. Though on the whole it tends to dissipate the Active impulse, it reinforces it in respect of cheerfulness and quickness.

It is always on the side of Emotional expression, facilitating both Socially favourable and unfavourable Emotional behaviour patterns.

II. *Activity.*—This is the only variable which in its positive form has no unfavourable behaviour aspects at all. It always operates in the direction of a maximal adaptation; directly through its own function,

indirectly through the influence it has on the operation of the other variables.

In its positive aspects it is (1) *the impelling force behind zeal and determination ;* (2) *responsible for general effectiveness ;* (3) *productive of a general Euphoria, experienced as Brightness and Optimism.*

It facilitates Cheerfulness and Good Humour, as well as all socially valuable conduct qualities: (*a*) through activating the most adaptive features of the Function pattern; (*b*) through prevention of complex formation and adaptive utilisation of Emotional discharge. Volitional effort, leading to the satisfaction of motives in a problem-solving and practical manner, is responsible for the behaviour pattern of the positive form of the Activity variable.

Its comparative absence is conducive to (1) *general Indifference ;* (2) *lack of adaptation, due to the unchecked emergence of the adverse functional behaviour qualities of the other two variables.*

III. *Emotionality.—Emotionality and Non-Emotionality do not, on balance, affect way of working and general effectiveness. Emotionality determines such pattern qualities as enthusiasm, nervousness, anger, discouragement. It strengthens* (1) *aggressive and assertive conduct,* (2) *adapted social responses such as affability and friendship,* (3) *brightness, variability, and aggressiveness of mood.*

Hence the positive form of the Emotionality variable can function in the direction of greater, as well as lesser adaptation, on balance more predominantly the latter than the former. *Non-Emotionality determines specific Indifference. It facilitates reserve, placidity, evenness of mood and passiveness rather than aggressiveness.* Emotionality emphasises the P.F. behaviour pattern. Non-Emotionality the S.F. behaviour pattern. Either can emphasise or detract from Activity. This variable therefore influences the strength, speed, and tone of a reaction. Except in affective responses, it does not determine the pattern of the reaction itself. By adding feeling tone to a motive, Emotionality can increase frequency of appearance of pattern reactions determined by other variables, or cause them to emerge where latent.

This analysis of the functional behaviour patterns of the three variables singly and in combination gives proof of their distinctness, which had not been sufficiently clearly established by the p.i. differences of criterion qualities (Table I).

The observed statistical overlap is the result of (a) *the Complexity of certain qualities, which are emergents of a definite quantitative relationship of the variables to each other* (e.g. *qualities such as "Accuracy," and qualities in the behaviour pattern resulting from a combination of very strong S.F. with very strong Emotionality and Activity) ;* (b) *the conservative effect of S.F.*

on Activity, on account of which the Inactive S.F. yet show more Active behaviour qualities than the equally Inactive P.F.

S.F. and Activity do not overlap, but their interaction is different from that between P.F. and Activity. The relationship statistically established is an indication of this difference.

(c) *The revelation of latent Primary patterns owing to the readier discharge of Emotional tension in the P.F., or owing to the existence of Emotional motives. P.F. and Emotionality do not overlap, but their interaction is different from that between Emotionality and S.F.*

In each case the statistically observed overlap proves on analysis to be the inevitable result of the interaction of the variables, the relationship established being consistent with their distinct function.

Overlap in other typologies has always meant the occurrence of the same or similar qualities as functions of different variables, without there being a clear genetic connection between them in each case. This indicates the unanalysed presence of a further variable. There is no evidence of such an overlap in our data.

IV. Miscellaneous Notes.

1. *The "Halo Effect" as a possible Systematic Error.*

Random errors must have occurred fairly frequently in the judgment of Temperament. Such errors could obscure, but not create, the correlations which this investigation has revealed.

Systematic errors are a more serious danger. Teachers might credit (*a*) intelligent children, (*b*) their favourites, with the more valuable behaviour qualities. This "halo effect" frequently occurs in personality judgments.

There is no difference in intelligence between the S.F. and the P.F.* Yet the former are credited with a more homogeneously good behaviour and far less blatant faults. Nor are the S.F. greater favourites of the teachers. They tend to be reserved and more retiring. The character sketches appended to the questionnaires indicate that among the P.F. some of the brightest and most attractive children are to be found. Nevertheless, the less favourable behaviour forms to which they are prone are as readily granted to them as positive and likeable qualities such as enthusiasm. Even of the poorest Inactives, most sympathetic accounts are often given. Though it is plain from the teacher's remarks that the child is hopeless scholastically, the personality sketch indicates a dissociation of the two attitudes and a genuine attempt at objectivity and giving each child its due. A random selection of such sketches is appended to illustrate our point.

* In an as yet unpublished research, no significant correlation was found between Function and Intelligence.

S.A.E. Type.—Case 1. Steady reliable boy with mind of his own. Works hard but results not outstanding. Does not stand much nonsense from others. Obliging.

Case 2. A very intelligent pupil, very quiet and very shy; but intelligent and forms his own ideas. Has a keen sense of humour and will often be seen laughing to himself over a joke, which the class as a whole has not noticed. About the most unobtrusive child in the class. Very good tempered, but shows a different spirit at home. His mother came to me one day and asked if I would tell him that she would take him to the show that afternoon. She had intended taking him, but had been prevented at first. He had been very annoyed, said he would return his ticket (scholars chit) to me, and left home in a real temper. He returned the ticket early that morning. When I told him he was going he said, "No! I'm not going" very determinedly. When I explained his mother had been to see me about it, he seemed satisfied, took his ticket, and smiled his usual quiet smile. I was amazed that he should show such independence and determination, and also temper.

S.A.N. Type.—Case 3. A very neat worker without a great deal of intelligence. Very pleasant and a hard trier. Retiring disposition with no flow of language.

Case 4. Very lacking in qualities that take the eye but steadily first in her year. Almost grown up in her reserve and steadiness of character.

Case 5. Quiet, sensible, reliable, honest. Not bright, but puts his best into it.

P.A.E. Type.—Case 6. One of the leaders of the class. Gives the impression of being quite a little man of the world. He has a sunny disposition and is always ready for a laugh. Is very eager to answer and to give information. I depend on him quite a lot and he takes responsibility well. He has not a strict sense of honour about his work. He copies if he can and looks at his tables, etc. He does not seem to be very ashamed of it either. At times he is very quiet but I think that he is thinking hard all the time. Tries to get out of a bit of work if he can. He is full of ideas and plans and never minds a joke against himself.

Case 7. An extremely original, sensitive child. Is critical of all and sundry, but yet is popular because of his original way of putting things. Is silent and morose at times. I should say is emotional. Will argue about everything.

P.A.N. Type.—Case 8. A fat boy, but full of energy and good humour. Pleasant manners and a frank attitude to the world.

Case 9. Is intelligent and rather credulous. Would not form his own opinion but take yours. Is rather quiet and easily cowed. He is very untidy in his work and often taken to task. Seems chastened but improves

little. Is inclined to be naughty behind the teacher's back. Is rather helpless and does not take responsibility well.

S.I.E. Type.—No sketch was found in this group, which only numbered 14 cases.

S.I.N. Type.—Case 10. He is very intelligent and yet slow. He jumped from standard I to III, and then was put down because he was too lazy to keep up. He finds great difficulty in explaining anything, because he is too halting and slow. The class is inclined to laugh at him a bit, but he is good natured and quite popular. He is serious about most things, and has little sense of humour. I think there is a sort of lag in his brain. I found it difficult to answer the questions (1) because he seems to fall between the alternatives generally; (2) because he is the sort of child which gives a wrong impression.

Case 11. Very slow and rather stupid. He is quiet and at times vacant. Slow to see a joke and the children make fun of him a bit. He is anxious to please and tries. He is interested in Nature Study and Geography, but always gets things muddled.

Case 12. She is a very quiet, unobtrusive little girl, rather credulous. Seems quite often to lack interest in her work and is inclined to be lazy. Sometimes seems to day-dream. Slow in answering questions and making up her mind.

P.I.E. Type.—Case 12. Rather a nervous, temperamental child. Is not very interested in her work, but draws well and is light and sprightly and a good dancer. I think very imaginative and rather credulous.

Case 13. A peculiar boy. It is difficult to interest him in his work. He is very inattentive, day-dreams and avoids work. He cries easily when reproved. Sometimes he seems stupid, but when made to work he can do it.

P.I.N. Type.—Case 13. Although very troublesome not unlikeable and not without certain good traits. Plays truant very often and to get out of scrapes will lie most blatantly.

Case 14. Is stupid at his work, draws very well, writes well, does handwork well. Helps at home with farm animals and can be trusted to do things. He is slow and moody. Sometimes seems much brighter than other times. Has a bad reputation with the staff except me. Used to play truant almost every day last year. He does not care about punishment and has little fear of the principal, but a kind word or a joke does a lot. Has a sort of lag—will go back and ask questions you have already dismissed. Very willing to help. Looks strong and healthy, but I think at times half starved. Sometimes has very vacant expression on his face. Very moody.

Case 15. A very quiet, lifeless sort of individual. It is difficult to

interest him in things. Does not care for sport. Hangs about the station generally, and is always dreaming. Can talk if he is really interested. Is not responsible, not nervous and I should say not emotional.

Though the "halo-effect" must have occurred in individual instances its influence on the correlations we discovered is probably negligible. In support of this view there is also the fact that the results obtained by widely different investigations * are in fundamental agreement.

2. *The Assumption regarding the S.I.E. Type.*

We assumed in Section II F. that the small S.I.E. group of but 14 cases is truly representative of the type, in that it displays a behaviour pattern consistent with that particular variable ratio. In discussing the behaviour function of variable ratios (Section III) the justification of this assumption was amply demonstrated. The S.I.E. are found to possess the application qualities of S.F., without the determination of Activity. Hence though they surpass the Primary Active types in attention and application, they are far below them in general effectiveness, though still superior in this respect to the Primary Inactive types. They display to a maximal extent typically S.F. emotional expressions such as crying, discouragement, and nervousness. They are least quickly offended of all emotional types, and only the S.I.N. exceed them in inability to be angered. They are less depressed and pessimistic of mood than the latter, showing some cheerfulness and occasional alternation. Owing to the beneficial influence of their Emotionality they are far more polite and affable than the S.I.N., less often indifferent, apathetic, and lifeless. If one were to add Emotionality to the S.I.N. pattern, as revealed in Table II, the result would correspond with the pattern actually found for the S.I.E.

3. *Retention of the Typological Form.*

A typology based on continuous variables is different from those commonly met with in which people are grouped according to the presence or absence of some complex personality attribute. In such static typologies the sole use of classifying at all is to indicate in a summary fashion the implications of the presence of one or other of these attributes in terms of behaviour. They cannot make a total statement about any Temperament or personality without over-simplification, contradiction, and omission. Most typologies fail wherever it is attempted.

When the behaviour function of continuous variables, singly or in combination and in different ratios of strength, has been accurately determined

* Heymans's Biographical Inquiry (24); the Heymans-Wiersma Heredity Inquiry (20); Hugo's School Inquiry (21); Wiersma's Racial Inquiry (25).

the usefulness of a typology vanishes. The Temperament of any subject plus its personality implications can be deduced from the variable ratio he is found to possess. Indeed, the existence of types and type-names can then only be confusing. For each type covers a range of ratios which, though alike in certain aspects, yet are different in others. Make a word stand for a detailed and complex structure and people will use the word. To divorce this word from its context is then an easy matter and implications are read into it, generalisations made from it which its author never intended. Thus Willemse (26) attacks the whole Heymans scheme through a misunderstanding of the word "phlegmatic," considered without reference to what it stands for.

Yet much as one would like to scrap all reference to types, work on the Heymans scheme has not yet reached the stage where that is possible. No clinical tests exist whereby the exact variable ratio of a subject can be measured. I have treated continuous variables as dichotomous, deducing from the data the real succession of behaviour qualities with continuous change from one extreme measure of the variable to another. If one now says that an individual falls within a certain type one knows at any rate the limits within which his temperament behaviour can vary. One knows that he is more likely to display qualities belonging to one range than to another. As by means of the criteria one can only roughly indicate the variable ratio, the use of such ranges or types cannot be dispensed with, no matter how artificial it may be. To minimise abuse and misunderstanding, and as a constant reminder of the basis on which we are distinguishing between people, symbols indicative of the variable ratio have been used in preference to the type names of Heymans.

V. Summary.

1. All Temperament behaviour can be reduced to three variables: (*a*) Primary—Secondary Function; (*b*) Activity—Inactivity; (*c*) Emotionality—Non-Emotionality.

2. These variables exist as distinct behaviour units which do not overlap functionally.

3. The form in which each variable expresses itself in concrete behaviour is modifiable along definite lines by the concurrent functioning of the other two.

4. Some Temperament behaviour qualities are emergents from the joint operation of the three variables in a special ratio of strengths; they cannot be understood in terms of any one of the variables singly.

5. The Temperament of an individual is a behaviour pattern produced by all three variables.

6. Given the strength of each variable this behaviour pattern can be worked out, the effect of interaction of the three variables being known.

7. For the sake of convenience and until each ratio can be accurately determined by means of clinical tests, ratios are grouped together into eight limiting categories which can be called Temperament types. Each type represents a known range of pattern variations.

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THE ALKALOIDS FROM THE BARK OF *STRYCHNOS HENNINGSII* (THIRD COMMUNICATION).

ISOLATION OF A SECOND CRYSTALLINE ALKALOID.

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(Read June 19, 1935. Revised MS. received September 10, 1935.)

(With Plate XXIV.)

Products Previously Isolated and Method Adopted.

Earlier papers (S.A. Journ. Sci., vol. xxvi, 1929, p. 50; and Trans. Roy. Soc. S. Afr., vol. xx, pt. i, 1931, p. 59) describe two alkaloids which have been isolated from this bark, a crystalline one obtainable only in very small amount, and an amorphous one which constitutes the bulk of the crude alkaloids and which has hitherto defied all attempts at crystallisation. The method adopted for their extraction was to percolate the ground bark to exhaustion with cold alcohol, to concentrate the percolate to the consistency of a thin syrup under reduced pressure, and to further concentrate the syrup by exposure to air. The concentrated solution so obtained was poured into cold water, the solution filtered until clear, treated with lead acetate and subsequently with basic lead acetate, and the excess of lead removed with sulphuretted hydrogen. The dilute acid solution, after shaking once with an ether-chloroform mixture, was repeatedly shaken with a large volume of purified chloroform, which removed small amounts of a crystalline alkaloid melting at 280·5–282° C. The amorphous alkaloid was obtained from the solution by rendering it alkaline with ammonia and extracting with chloroform.

In the earlier communications the first author made reference to his occasional failure to obtain the crystalline alkaloid, and tentatively put forward the suggestion of seasonal variation. In a subsequent investigation of so-called winter bark collected in July 1933 in the Pirie Forest, a satisfactory yield of the crystalline alkaloid was obtained (0·03 per cent. from 4 shakings, not exhausted). The trouble previously experienced was

traced to the presence of traces of acid which inhibit crystallisation. It is necessary to shake up the chloroform extract of the dilute acid solution repeatedly with small quantities of water until every trace of acetic acid has been removed.

Modification of Extraction Method.

It was found advantageous to modify the method previously adopted by concentrating the alcoholic extract under reduced pressure almost to dryness, dissolving the residue in water as before, and shaking the aqueous solution with petroleum ether for the removal of fatty material. The extraction with ether-chloroform and with purified chloroform was then carried out as previously described.

Formula and Properties of Crystalline Alkaloid.

From plant material which had been sent to the firm of E. Merck, Darmstadt, Germany (Trans. Roy. Soc. S. Afr., vol. xx, pt. i, p. 59, 1931), for physiological tests, some crystalline alkaloid had been isolated and analysed. Microanalyses were also carried out on some of our own material (indicated as R. and S.).

R. and S.

3·818 mg. substance;	9·391 mg. CO_2, 2·220 mg. H_2O.	C 67·08. H 6·51 per cent.
3·457 mg. ,,	0·239 c.c. N. 25° C. and 624·5 mm.	N 6·51 per cent.
4·432 mg. ,,	2·237 mg. AgI (Pregl-Zeisel),	OCH_3 6·67 per cent.
3·907 mg. ,,	2·135 mg. AgI (Pregl-Zeisel),	OCH_3 7·21 per cent.

$C_{24}H_{28}N_2O_5$ (424): Calc. C 67·92, H 6·6, N 6·6.
$C_{23}H_{28}N_2O_5$ (412): Calc. C 66·99, H 6·80, N 6·80.
$C_{22}H_{25}N_2O_4$ (OCH_3): Calc. OCH_3 7·55.

Found: (Merck) C 66·50, 66·11, 66·78; (R. and S.) 67·08; (Merck) H 6·56, 6·39, 6·49; (R. and S.) 6·51; (Merck) N 6·48, 6·50, 6·64; (R. and S.) 6·51.

Found: (OCH_3) (R. and S.) 6·67, 7·21. No methylimido groups (Herzig and Meyer).

Average value of molecular weight previously found, 383. With the exception of one set of figures, all the results are in good agreement with the formula suggested. This formula differs from that originally suggested.

The formula previously put forward tentatively was based on only two analyses which were carried out on material that had been kept for some time. The samples for both determinations were taken from the

same batch. It had been found repeatedly that the alkaloid, when freshly extracted, has a higher melting-point than that of old material, suggesting that slight decomposition takes place. Recrystallisation, however, brought about a rise to the value of the fresh stuff.

The alkaloid appears to be phenolic. It is soluble in aqueous caustic-soda solution, and is precipitated unaltered by sodium bicarbonate, but it gives no distinctive colour with ferric chloride. Attempts to methylate it in chloroform solution with ethereal diazomethane proved inconclusive. On account of shortage of material the attempt had to be carried out with extremely small quantities of material. The action of the methylating agent is possibly inhibited or unduly retarded by the fact that ether precipitates the alkaloid from the chloroform solution.

Determination of rotation:

(I.) 0·0582 gram substance in 22·70 grams absolute alcohol, 4-dm. tube.

(II.) 0·0582 gram substance in 32·594 absolute alcohol, 4-dm. tube.

I. $[\alpha]_D^{12°} = -80·9°$, II. $[\alpha]_D^{11°} = -80·2°$.

Solubility in absolute alcohol approximately 0·7 gram per 100 grams of solvent at 13° C.

Isolation of a Second Crystalline Alkaloid.

In the original publication about the crystalline alkaloid (*loc. cit.*, p. 53) it is stated that the crystals obtained from acid solution by extraction with chloroform were repeatedly triturated with ether. The accumulated residues from the ether washings were extracted by continuous hot percolation with ether in a Soxhlet. The extract appeared to consist of stoutish prisms and needles embedded in a yellow paste. The prisms adhered to the sides of the flask and could be separated from the remainder by washing with cold ether. The prismatic crystals had a white granular material attached to them. They are sparingly soluble in ether, ethyl acetate, and toluene, more readily in benzene, acetone, chloroform, methanol, and ethanol. Attempts to obtain the crystalline product free from the adhering granular matter by means of solvents failed. The prisms could only be recrystallised by very slow evaporation of an ether solution, but the results were erratic, and the method did not prove effective as a means of separating the adhering granular material from the crystals. Some particularly big, well-developed crystals were singled out with a pair of tweezers and the surface cleaned with a needle. This material was analysed, and the results are indicated by the words "original crystals."

Subsequently it was found that the crystals could be purified by vacuum sublimation. The first sublimate (0·03 mm. 190–200° C.) yields two different types of crystals. Those of the lower zone nearer to the heater

are squat prisms and represent the bulk of the sublimate. Farther away from the heater needles are formed, but there is no clear line or zone of demarcation between the two types. A portion of the prismatic crystals can be readily detached by shaking the cut sublimation tube. They appear to be homogeneous under the microscope, and show a sharp melting-point 214·5–215° C. (corr.), which does not rise on resublimation. The needle-shaped crystals have a much lower melting-point (191–194°), but do not appear to be pure. The amount of this material of lower melting-point at present available is inadequate for further investigation.

The sublimation process was carried out in a sealed tube heated in an electric furnace, the temperature of which could be exactly regulated. The rate of sublimation was extremely slow and gradually fell and finally ceased completely. By re-evacuating, the rate could be again accelerated. Probably some of the impurity attached to the crude material undergoes decomposition, producing gaseous products and partly destroying the vacuum. As the needle-shaped crystals are more volatile than the prisms, the latter could be obtained pure by subliming for a short time to remove the needle-shaped crystals, and then transferring the unsublimed residue to a new tube.

The results are:

Original crystals: 3·879 mg. 9·623 mg. CO_2 : 2·485 mg. H_2O.
Sublimed ,, : 3·826 mg. 9·531 mg. CO_2 : 2·502 mg. H_2O.
Original ,, : 3·803 mg. substance. 0·281 c.c. N, 22° C., 621 mm.
Sublimed ,, : 2·350 mg. substance. 0·172 c.c. N, 21·5° C., 621·5 mm.
Original ,, : 4·706 mg. substance. 4·988 mg., AgI (Pregl-Zeisel).
$C_{24}H_{30}N_2O_5$: Calc. C 67·6: H 7·04: N 6·57.
Found: C 67·66, 67·94: H 7·17, 7·32: N 6·99, 6·94.
$C_{22}H_{24}N_2O_3(OCH_3)_2$: Calc. (OCH_3) 14·55. Found: 14·00.

1·068 mg. alkaloid dissolved in 4·022 mg. camphor. Depression of melting-point, 23·8°. Mol. wt., 446. Depression calculated from solidifying point (according to Carlsohn, Ber., vol. lx, p. 473, 1927), 25·8°. Mol. wt., 412; calc., 426.

To the first crystalline alkaloid the formula $C_{23}H_{28}N_2O_5$ had been ascribed. This new one differs from it by an increment of CH_2. When a sufficient amount of material is available attempts will be made to ascertain whether the two alkaloids are monomethoxy and dimethoxy derivatives of the same mother substance.

The melting-point of the crude base suggested that it might possibly be impure β-colubrine. A little of this base was, therefore, procured for comparison. A mixed melting-point showed a considerable lowering, and the analytical results exclude any possibility of identity. With

Froehde's reagent, however, our base gives a similar violet colour reaction to the two colubrines, gradually turning to blue (reduction ?) (Helv. Chimica Acta, vol. xiv, p. 1001, 1931).

Summary and Conclusions.

(*a*) The investigation of the crystalline alkaloid previously isolated from the bark of *Strychnos Henningsii* is continued. Analyses of the material isolated by the authors, as well as of material prepared by the firm of E. Merck of Darmstadt, Germany, suggest the formula $C_{22}H_{25}N_2O_4(OCH_3)$. This formula differs from the one previously put forward.

(*b*) The compound contains one methoxyl group, but no methylimido group.

(*c*) The alkaloid is probably phenolic, but attempts to methylate it with diazomethane for the purpose of ascertaining the number of hydroxyl groups proved abortive.

(*d*) The crude alkaloid is accompanied by very small quantities of a second crystalline alkaloid, which can be removed by continuous percolation with ether and purified by high vacuum sublimation (0·03 mm., 190–200° C.).

(*e*) Analyses suggest the formula $C_{22}H_{24}N_2O_3(OCH_3)_2$, differing from that of the first crystalline alkaloid by an increment of CH_2. The two alkaloids may possibly be the monomethoxy and dimethoxy derivatives of the same mother substance.

(*f*) The melting-point of this new alkaloid is 214·5–215° C. (corr.), its molecular weight has been found as 446 and 412. The formula demands 426. With Froehde's reagent the alkaloid gives colour reactions similar to those of the two colubrines recently isolated from the mother liquors of the strychnine industry.

(*g*) There is also evidence of the presence of a third crystalline alkaloid. The investigation is being continued.

The authors desire to place on record their indebtedness to the Research Grant Board of the Union for a grant, part of which was used to defray the expenses of the investigation. They also desire to make acknowledgments to Dr. Kurt Warnat of the Hoffmann-La Roche & Co., A.-G. of Basel, Switzerland, for placing a specimen of β-colubrine at their disposal; to Dr. O. G. Backeberg, of the University of the Witwatersrand, for carrying out some of the micro-analyses; and to the Officers of the Department of Forestry for procuring the plant material for the above investigation.

FIG. 1.—First Crystalline Alkaloid, Recrystallised from Alcohol.

FIG. 2.—Second Crystalline Alkaloid, Sublimed.

THE SMITHFIELD "N" CULTURE.

By C. van Riet Lowe,

Director, National Bureau of Archaeology, Research Professor, Prehistoric Archaeology, University of the Witwatersrand.

(Read July 17, 1935.)

(With one Text-figure.)

Introduction.

Mr. A. J. H. Goodwin concludes his contribution on "A New Variation of the Smithfield Culture from Natal" with the remark that "it would appear probable that in Smithfield 'N' we have a series showing affinities to both Smithfield A and the Fauresmith throughout its known history. This variation seems to have constituted a survival from the earliest Smithfield times, finding its way up, with little change, to a time comparable with the latest." (1)

As the affinities between this new variation of the Smithfield Culture and the Fauresmith, as described by Goodwin, are rather slender, I recently made a point of examining the position on new ground. Captain G. A. Gardner of Hebron, Lion's River, had submitted to me a number of notched and "strangled end-scrapers" so typical of the Smithfield "N" variation, as named and described by Goodwin, that I availed myself of the earliest opportunity to visit the scene of his discoveries. Two sites have been investigated. The first on the farm Totheng, about $2\frac{1}{4}$ miles from Lion's River Station, marked **"L"** on the accompanying map, the other on Webster's Farm, about $4\frac{1}{2}$ miles north of Michael House School, Balgowan —both in Natal.

These sites are approximately at the southern apex of a triangle with sides 45 miles from Weenen to the north and 55 miles from Krantzkop to the north-east—the sites mentioned by Goodwin—marked **"W"** and **"K"** on the accompanying map.

The implements are found on an old land surface about 12 inches below the present natural ground level.

Description of Implements and Sites.

Site No. 1 : Totheng.

The Totheng site yielded typical Smithfield duck-bill end-scrapers (a few of which are double-ended), thumbnail scrapers, strangled end-scrapers, side- and concavo-convex scrapers, grind-stones, a bored stone, palettes, potsherds, cores and fabricators (detaching hammers and trimming stones). But for the great number of notched scrapers that include all the forms illustrated by Goodwin and a few large concavo-convex scrapers, the congeries is completely Smithfield "B."

The material throughout is indurated shale, the source of which is unknown. No indurated shale has been traced in the vicinity of the site, and there can be no doubt that the congeries represents the industry of the site. In other words, the industry is homogeneous and the association of types as completely established as it can be.

Site No. 2 : Webster's Farm.

At Webster's Farm Mr. Rodney C. Wood is still busy excavating, but his assemblage is already greater than that from Totheng and equally interesting. Here the congeries is similar to that from Totheng, but includes the following additional elements: one grooved stone, three crescents, and two angle gravers, rather like those from the Umgazana Variation of the Smithfield Culture. (2)

As at Totheng, there can be no doubt whatever that all these artifacts combine to form the industry of the site. Both sites are carefully chosen and well-protected home- and factory-sites in sheltered re-entrants on the banks of streams. But for a few small scrapers of thumbnail type in chalcedony and one crescent in quartz, all the artifacts are of indurated shale, and no indurated shale has been noted in the vicinity. As at Totheng, so here the material must have been transported to the site from some distance.

True Fauresmith elements are completely absent.

General.

These occurrences throw so much fresh light on this "N" variation of the parent Smithfield Culture that I feel impelled to record them. For comparison with original records (3), we may therefore accept the following types as belonging to and representative of this peculiar variation:—

1. Strangled end-scrapers.
2. A variety of notched scrapers, including the **Y** shape.
3. Duck-bill end-scrapers.

4. Thumbnail scrapers.
5. Side-scrapers.
6. Concavo-convex scrapers.
7. Crescents.
8. Angle gravers.
9. Grind-stones (top and bottom).
10. Bored stone.
11. Grooved stone.
12. Palettes.
13. Pottery.
14. Cores, detaching hammers, and trimming stones.

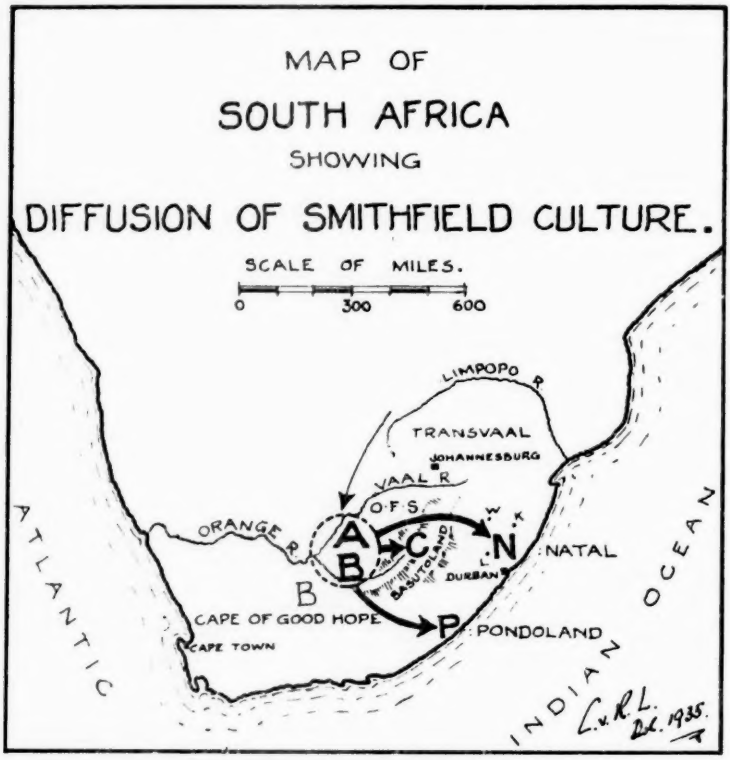
Conclusions.

It would appear that just as the Umgazana Variation of the Smithfield Culture owes its peculiarities to a migration of folk practising an early Smithfield Culture from the upland grassy plains of the Free State to new employments in a new environment and latterly to a changed diet which gave rise to a specialised bone and burin industry at the coast (4), so this "N" variation owes its peculiarities—a variety of conventionalised notched scrapers—to a migration from the same grassy plains to the well-afforested regions of Natal. Here it should be noted that the notched scraper was not a special invention of those who practised the Smithfield "N" Culture. It exists in "A" and "B," but the increase and specialisation in this form of tool ultimately becomes the most marked feature of the culture. The abundance of timber in Natal must have led to specialisation in tools for working and shaping sticks, clubs, arrows, etc. The presence of simple angle-gravers and crescents in the Natal congeries can be appreciated when we think how naturally these tools can be derived from an early Smithfield Culture when those practising it migrate from the highveld over mountains (where indurated shale seldom appears) to regions so entirely different.

Goodwin has pointed out that certain Rhodesian occurrences of a variety of notched scrapers of Later Stone Age type "represent an influence which entered Zululand and Natal to produce the Smithfield "N" variation by impact upon a normal Smithfield "A" or "B" Culture already present in South Africa. (5) In South Africa, yes, but where are these normal Smithfield "A" or "B" Cultures in Zululand and Natal? We do not know of any.

While recognising the occurrence of certain Smithfield "N" elements in the north, for example in Rhodesia, the absence of normal Smithfield "A" and "B" industries in Natal and the full series of Smithfield "N" elements here described, force me to look for a more satisfactory explanation of this peculiar variation of the parent culture.

In the first place, I cannot escape the suspicion that the home of the Smithfield Culture lies in the great triangle above the confluence of the Vaal and Orange Rivers in the south-western corner of the Orange Free State and its immediate surroundings. Here the culture was intensely



A: } CENTRE OF DIFFUSION.
B: } HIGHVELD GRASSY PLAINS.
C: MOUNTAINOUS . DRAKENSBERG.
N: HILLY FOREST COUNTRY.
P: PONDOLAND . COAST.

practised over a long period of time, and it would seem that from this home migratory movements were initiated that led to the diffusion and ultimate variation of the parent theme as set out diagrammatically on the accompanying map. The position may be summarised as follows:—

1. The "A" and "B" phases, the relative horizons of which are still imperfectly understood, belong essentially to the upland grassy plains

of the Free State highveld. That the beginnings of "A" go back further than do those of "B" is established (*a*) by the association of "A" forms with the Fauresmith Culture, and (*b*) by the frequent occurrence of these and other "A" forms with a heavier incrustation or deeper patination than is general in "B." But whether "A" is consistently older than "B" or not, we cannot say. Certain occurrences lead one to conclude that while we have every reason to believe that "B" is an offshoot from "A," nevertheless the two industries continued to be practised side by side for an appreciable period of time, and continued in this fashion in the great triangle above the confluence of the Vaal and Orange Rivers referred to above.

2. "C" belongs essentially to the mountainous regions that border on and include Basutoland to the east. Here indurated shale is very scarce, and the bearers of the parent Smithfield Culture were obliged to use chalcedony, chert, and quartz derived from the volcanics of the Drakensberg; and so a new variation arose, a variation that ultimately led to a new culture (6) set in motion by new materials to hand and a new mode of life.

Contacts with other cultures may also have been made—a possibility that cannot be ignored—where each borrowed from the other; but whatever happened, the fact emerges that this variation of the main theme did arise and was established in the mountains.

3. "N" belongs to the afforested regions of Natal, and if my suspicions about the diffusion of the parent culture from the Free State are correct, settlement in Natal could only have been effected *after* the mountains had been crossed and an indurated shale area again entered. This accounts for the regeneration or survival of original "A" and "B" forms, as well as the occurrence of certain pygmy "C" elements, for the latter were borne on the migratory wave on its way down the far side of the Berg.

The presence of a variety of notched scrapers in Rhodesia does not mean that we must necessarily look to Rhodesia for the origin of similar forms in Natal. Later Stone Age elements may certainly have filtered into Natal from Rhodesia and affected the development of the Smithfield "N"; but when one studies the complete Smithfield "N" assemblage as here described, it would certainly appear to be much more closely related to similar assemblages from the Orange Free State than to these end-, side-, and notched scrapers from Rhodesia. Rhodesia lacks most of the essential elements of the Smithfield Culture as a whole.

4. The Umgazana Variation, which I have labelled "P" (for Pondoland) in the diagram, belongs essentially to the coastal belt that was reached by a migratory movement that was never out of an indurated shale area for long—a route along which the geological formations are appreciably

unlike those encountered on the more northerly crossing of the Drakensberg. Certain original "A" and "B" forms are therefore more persistent, and the ultimate changes and additions (bone tools and burins) were evolved and established rather by demands of new employments, an altered diet and a new mode of life than by any change of material to hand.

If the diffusionist idea is correct and the influence of altered environmental conditions and material to hand is as potent as it appears to be, then this Smithfield "N" complex is merely one of five marked yet intimately related variations of some common parent. First we find "A" ranging from the Limpopo to the Orange, with the great habitat of its makers in the south-western corner of the Orange Free State. The great abundance of home- and factory-sites of this period in this area tells of a long occupation. Gradually "B" evolved, and with its growth man moved farther afield—a movement most probably set in motion by the demands of an increased population. So "B" gradually spread up and down the water-courses that feed and drain this area, until it ultimately covered the whole of the Free State and a very considerable portion of the Cape.

Once movement was initiated, it is not difficult to appreciate further diffusion and to visualise and understand the ultimate development of the "C," "N," and "P" (or Umgazana) variations of the parent culture in the more remote areas.

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(3) Van Riet Lowe.—"The Smithfield Industry in the O.F.S.," Ann. S.A. Mus., vol. xxvii, pp. 151–235, 1929.

(4) Van Riet Lowe in Chubb, *op. cit.* Note, p. 264.

(5) Goodwin.—"The Rhodesian Origin of certain Smithfield N Elements," Proc. Rhod. Sci. Ass., vol. xxxiv, pt. 1, 1934.

(6) Van Riet Lowe.—*Op. cit.*, p. 184.

AN APPARATUS FOR THE QUANTITATIVE ESTIMATION OF PHYTOPLANKTON.

By W. J. Copenhagen.

(MS. received August 9, 1935.)

(With Plate XXV and one Text-figure.)

At the meeting of the Royal Society of South Africa on the 17th October 1934, a demonstration was given to the members present of a new type of apparatus for the quantitative estimation of phytoplankton.

Experiments have been continued during the past nine months, and the apparatus has functioned in a most satisfactory manner.

Introduction.

The distribution in the sea of the unicellular plants comprising the phytoplankton is far from regular. Both the quantity and species vary as one proceeds from the shore out to the open sea. Likewise comparatively dense communities may be met with in patches, and also areas of apparent barrenness.

In addition to this irregular distribution, a variation is also encountered as one proceeds below the surface down in the depths to the limits of photosynthesis.

For the quantitative estimation of phytoplankton, the towing of the usual half-metre, and metre, plankton nets, for definite periods of time, yields results that are in no way quantitative. Variation in currents and drift of the towing ship are factors that are impossible to control, and considerably influence the amount of water passing through the net.

The only strictly quantitative method is by centrifuging a sample of water and counting the plants in it. The quantity of water that it is possible to centrifuge is extremely limited, and, unless a large number of samples is taken from many different points, counts will not give a true representation of the plant population of any given area.

The use of a water meter in the mouth of a net for measuring the volume of water passing through, and the subsequent filtration of it, was first suggested by Nansen in 1915.

Recently, however, Harvey (1934) described an apparatus in which a water meter was incorporated in a modified 30½ cms. diameter 200-mesh plankton net for recording strictly quantitative results. The catch here is collected at the extremity of the net in a small bucket. This is subsequently removed and washed on to a small disc (also of 200-mesh bolting cloth).

The disc containing the catch is placed in 80 per cent. acetone, which dissolves the yellow-green pigment from the phytoplankton. The quantity of pigment is then estimated by comparing the known volume of acetone solution with colour standards.

Owing to the necessity, however, of the slow towing speed (1–2 knots) it would appear that Harvey's quantitative apparatus is limited in its use to the conditions where the ordinary half-metre 200-mesh plankton net can be used.

Such nets are usually towed for 15–30 minutes, and the area covered is in consequence small. A fair number of such hauls are again necessary here before representative values can be obtained.

Owing to the irregular distribution of the phytoplankton even in a distance of 3 miles, the possibility was considered of a long, thin volume of, say, ½ inch in diameter (*i.e.* about 600 litres) yielding a representative sample. To obtain a strictly quantitative picture over this distance it is considered necessary to take at least *three* such volumes, *i.e.* sectional cylinders of ½ inch diameter and 3 miles in length. These could be taken at depths of 1 metre, 15 metres, and 30 metres.

With such an object in view, an apparatus was designed, and subsequently constructed, that could be drawn through the sea either vertically, obliquely, or hauled horizontally.

Description of Apparatus.

The apparatus consists essentially of a brass tube 2 inches in diameter. At the one end a detachable funnel is fitted with a towing bar (at right angles to the tube). Attached to the towing bar is a short loop of flexible steel wire that is secured to the towing rope.

Owing to the resistance offered by the 200-mesh silk, it was found necessary to force the water through the ½-inch opening by means of a funnel. The ½-inch opening (see fig. 1) is fitted with a circular disc with ⅛-inch holes. Next to the funnel is a water meter (Glenfield rotary meter). This consists essentially of a bakelite impellor fitted with an agate-bearing plate. This is balanced on a brass pin fitted with an agate pivot (see photo). The bakelite impellor is connected with suitable gearing on to the usual counting meter device.

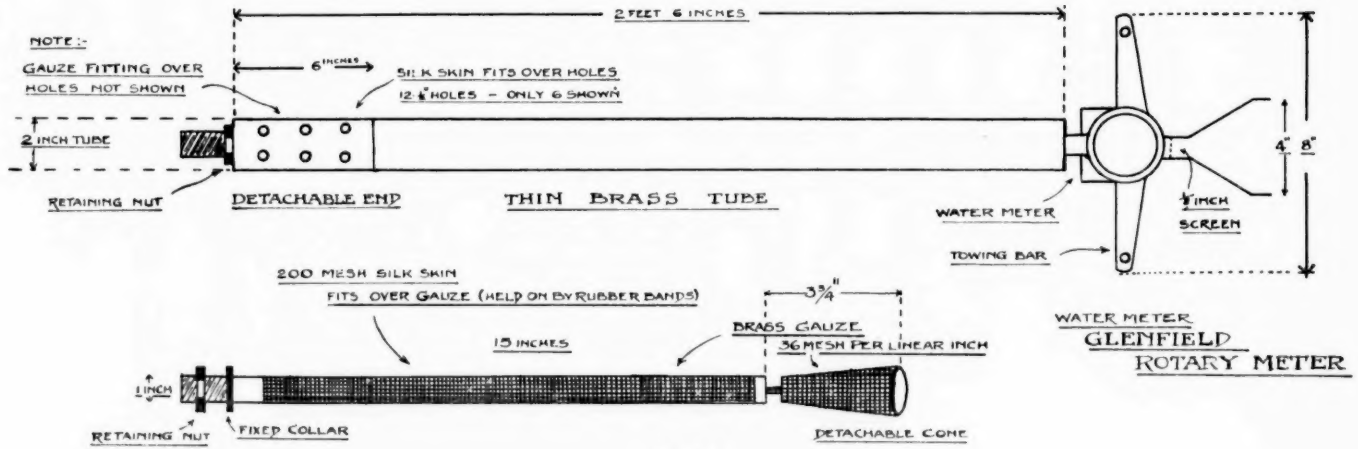

2 FEET 6 INCHES
NOTE:-
GAUZE FITTING OVER HOLES NOT SHOWN
6 INCHES
SILK SKIN FITS OVER HOLES
12 ½" HOLES - ONLY 6 SHOWN
2 INCH TUBE
RETAINING NUT
DETACHABLE END
THIN BRASS TUBE
WATER METER
TOWING BAR
4"
8"
½ INCH SCREEN
200 MESH SILK SKIN
FITS OVER GAUZE (HELD ON BY RUBBER BANDS)
3¾"
BRASS GAUZE
36 MESH PER LINEAR INCH
15 INCHES
1 INCH
RETAINING NUT
FIXED COLLAR
DETACHABLE CONE
WATER METER
GLENFIELD
ROTARY METER

FIG. 1.

As the apparatus is towed through the water, the water is forced by the funnel through the ½-inch opening. It passes through the ⅛-inch screen and through the meter. It then encounters a brass gauze cone (36 mesh per linear inch). This serves as a coarse filter for copepods, etc. The water is now filtered through the 200-mesh silk skin on the central column, or through the silk covering the 12 holes in the detachable end.

At the end of the run the apparatus is taken out of the sea, held in a vertical position to allow the water to drain. (This usually drains out to the lower or middle set of ½-inch holes in the detachable end.) The end is unscrewed, and the water and collected catch is poured into a suitable jar.

The detachable cone is unscrewed and the rubber bands removed. The silk skin (from the central gauze column), and from the outside of the detachable end, is carefully removed and placed into the jar containing the liquid, care being taken not to touch the exposed surface of the silk. Note, a rubber washer is placed under the fixed collar to prevent the catch from leaking out of the detachable head.

In practice it was found that by electroplating the outside of the detachable end it was easy to observe any trace of phytoplankton accidentally left during the removal of the silk skin.

Calibration of the Meter.

The meter was kindly calibrated and checked after affixing in the brass tube by S. Bassett, Esq. The following figures were obtained:—

½-inch (Glenfield Meter) fitted to Brass Tube.	Standard Tank (Standard Meter).	Time.	Remarks.
100 galls. (454·6 litres)	101 galls. (459·2 litres)	9½ mins.	1 per cent. low.
5 ,, (22·7 ,,)	5 ,, (22·7 ,,)	24 ,,	Correct.
5 ,, (22·7 ,,)	5 ,, (22·7 ,,)	50 ,,	Correct.

Lower rates than 5 gallons in 50 minutes gave results that were inaccurate.

It is thus observed that at rates of the order of 48 litres per minute the readings are 1 per cent. low, while with rates up to and including ½ litre per minute correct results are obtained.

Under working conditions it was found that when towing the apparatus from a motor yacht at a speed of about 5 knots, approximately 5 litres of water passed through in 1 minute. Naturally at higher speeds more water

is forced through. The relative dispersion of the plankton was a deciding and limiting factor.

Owing to the limited filtration surface it is a useful precaution to have the apparatus in after about 30 minutes' run and note the reading.

A reading is again taken after another 10 minutes' run in order to observe that the rate of flow is not less than $\frac{1}{2}$ litre per minute.

Plankton catches were also obtained with the ordinary half-metre 200-mesh net on all the occasions that the apparatus was used. These catches were taken at the beginning and end of the run. It was found that the catch was very similar to that obtained with the apparatus under description.

When dense gelatinous catches were obtained the run with the apparatus was limited to 30 minutes' tow (at speeds from 4 to 6 knots). Fresh silks were then introduced and another 30 minutes' tow continued.

At other times it was found that after 50–70 minutes the meter was registering satisfactorily. Under practical conditions it was found that on the usual runs some 200–300 litres of water were filtered. This is about $\frac{1}{3}$ to $\frac{1}{2}$ of the theoretical volume of the $\frac{1}{2}$-inch diameter cylinder on a 3-mile run.

Duplicate runs over approximately the same ground within 2 hours gave readings within 10 per cent.

In virtue of the gauze backing on the 200-mesh silk it has been found possible to tow the apparatus at speed up to 8 knots. At lower speeds, *i.e.* at 6 knots, the bulk of the catch does not appear to suffer any appreciable damage.

Estimation of Catch.

The jar containing the catch and used silk skins are brought to the laboratory, where the liquid portion of the catch is filtered through 7 cm. diameter No. 4 Whatman filter-paper, in a Büchner funnel at the suction-pump.

The silks are pressed out and all adhering water removed. Phyto-plankton removed by the fingers is washed with sea water on to the surface of the filter-paper. The silks and filter-paper are now placed in a measured volume of 80 per cent. acetone in wide-mouth glass-stoppered vessels (to prevent evaporation) and left for 24 hours. At the end of this period the solution is filtered and compared with the standard colour solutions of nickel sulphate and potassium chromate, as described by Harvey (1934).

Pigmented zooplankton must be watched for, as these are likely to give erroneous results.

SUMMARY.

A new type of apparatus is described for the quantitative estimation of phytoplankton.

Certain advantages over existing apparatus are claimed:

1. A representative sample of any given area is more easily obtained.
2. A complete removal of the catch can be effected.
3. The catch can be collected at speeds up to 8 knots.
4. A rapid interchange of the filtering surface is possible.

ACKNOWLEDGMENTS.

I desire to express my thanks to R. Turner, Esq., M.B., Ch.B., for kindly taking the photograph, and to the assistance of Engineer-Capt. R. Montgomery, R.N.

I am indebted to Messrs. H. G. Stephens & Son, Art Metal Workers, for assistance in the construction of the apparatus. Likewise to S. Bassett, Esq., for his courtesy in the calibration of meters.

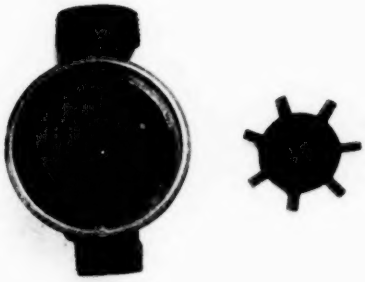
Finally, I have to acknowledge a grant for the expense of this investigation from the Research Grant Board.

REFERENCE.

HARVEY (1934).—"Measurement of Phytoplankton Population," Jour. Marine Biol. Assoc., vol. xix, No. 2, 1934.

NOTE.—Since going to press Hardy's paper ("The Continuous Plankton Recorder," Rapp. Conseil Intern. Explor. Mer., vol. xcv, 1935) has been received.

This does not appear to record the volume of water filtered.



DETAILS OF BAKELITE IMPELLOR OF WATER METER.

W. J. Copenhagen. *Neill & Co., Ltd.*

TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXIII.

MINUTES OF PROCEEDINGS.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 21, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. Rogers, was in the Chair.

The President announced the death of Sir Thomas Muir, a foundation Fellow of the Society, a regular contributor to the Transactions, and for some years President of the South African Philosophical Society. The President added that in the death of Sir Thomas, not only South Africa, but the world, had lost one of its greatest mathematicians. It was resolved that a letter of condolence be sent to Mrs. Spilhaus, daughter of the deceased.

Business:—

The Reports of the Hon. General Secretary and the Hon. Treasurer for the year 1933 were read and adopted.

The following were elected as Officers and Members of Council for the year 1934:—

President, Dr. A. W. Rogers; Hon. Treasurer, Professor L. Crawford; Hon. General Secretary, A. J. H. Goodwin; Hon. Editor of Transactions, Professor R. S. Adamson; Hon. Librarian, Professor E. Newbery; Members of Council, Professor A. Brown, Dr. J. P. Dalton, Dr. E. L. Gill, Dr. S. H. Haughton, J. Hewitt, Professor W. A. Jolly, Professor A. Ogg, Dr. E. P. Phililps, Dr. M. Rindl.

Following the change of constitution authorised by ballot in 1933, the offices of Hon. Editor of the Transactions and Hon. Librarian were included as additional Members of Council.

Professor A. Ogg and Dr. J. P. Dalton were nominated as Vice-Presidents of the Society for 1934.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

The President, Dr. A. W. Rogers, was in the Chair.

Business:—

The Minutes of the Meeting held on October 18, 1933, were confirmed.

Communications:—

"A new Variation of Smithfield Culture from a Cave on the Pondoland Coast," by E. C. Chubb, G. Burnham King, and A. O. D. Mogg (communicated by C. van Riet Lowe.)

A description of the excavation of a cave at the mouth of the Umgazana River, some ten miles south west of Port St. John's. Pottery was found in the later layers, and stone implements in all the occupational strata. There can be no doubt that the congeries is assignable to the Smithfield Culture, but shows a variation from the typical congeries of this division from open sites.

"The Stratification of the superficial Deposits at Mossel Bay and the Age of the Mossel Bay and other Lithic Industries," by T. F. Dreyer.

"An Anatomical Study of the Roots of Grasses," by A. P. Goossens.

The development of the roots and its tissues is discussed.

The roots of grasses arise endogenously and the root is provided with a root-cap with which a mucilaginous substance is associated.

Mucilage usually occurs on the epiblem in which soil particles become embedded. Root hairs occur all over the whole length of the root, and usually become cemented to the soil particles, to form a sheath. An exodermis is found in grass roots which becomes differentiated into short and long cells. A well-marked endodermis separates the cortex and the stele. In most grasses there is a well developed sclerenchyma which supports the perforated cortex. A perforated cortex is a characteristic feature of grass roots, and seems to be associated with a better oxygen supply.

The stele of grass roots varies very little. The pith is important in that reserve food is stored in it during the resting period.

"Neolithic Stone Implements found at Regina in the Western Transvaal," by Margaret Orford (communicated by R. A. Dart).

The two specimens from the Western Transvaal described in this paper afford additional evidence of the presence of a highly developed Neolithic culture in South Africa. The association of Smithfield rings and Neolithic daggers proves the existence of a definite link between these industries. A tentative suggestion as to the contemporaneity of the Neolithic and Bronze Ages in South Africa has before been put forward. The style and finish which these objects present suggests the possibility of their being copies of Bronze objects. The material of which they are composed was used in the construction of ornamental objects from the Zimbabwe Culture. We may say, therefore, that these specimens form a link between the Neolithic, Smithfield, and Zimbabwe industries.

"Bird Population Studies, V.: An Analysis of the Avifauna of the Jeans School Station, Mazabuka, Northern Rhodesia," by J. M. WINTERBOTTOM.

"Water Absorption by Leaves of Crassula," by M. A. KEAY (communicated by R. S. ADAMSON).

Exhibition:—

"Abnormal Dentition of a Bushman Skull," by A. J. H. GOODWIN.

The exhibit consisted of the mandible and cranium of an individual of San (Khoisan) Race, associable with Smithfield B. material from a cave on the farm Oakhurst, near George. The skull suggests an adult in the early twenties.

In the upper jaw the two lateral incisors had been forced back out of alignment as a result of marked congestion. To counteract similar congestion in the lower jaw, both first molars had been removed. A further point of interest is the complete absence of the third molars of the upper jaw. The teeth are somewhat worn, and show no signs of dental caries.

This is the earliest example of primitive preventive dentistry so far recorded from South Africa.

A. J. H. GOODWIN,
Hon. General Secretary.

REPORT OF THE HON. GENERAL SECRETARY FOR 1933.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "The Class Enteropneusta, with special reference to the South African species," by C. VON BONDE.

2. "The Distribution of the Ionising Particles of the Penetrating Radiation with respect to the Magnetic Meridian," by J. P. T. VILJOEN and B. F. J. SCHONLAND.

3. "Middle Stone Age Industries near Bloemfontein," by T. F. Dreyer.

4. "Electrolytic Refining of Mercury," by E. Newbery and S. M. Naudé.

5. "Nivenia, Vent. and Nivenia R. Br.," by N. E. Brown.

6. "A Revision of the Genus *Lopholaena* DC.," by E. P. Phillips and C. A. Smith.

7. "The Appearance and Spread of a Senecio rare to the Cape Peninsula," by M. R. Levyns.

8. (*a*) "The Effects of Castration on the Urinary Creatinine of Female Rabbits. (*b*) The Effects of Injection of Ovarian Suspensions, Ovarian Extracts and Testicular Extracts on the Urinary Creatinine of Normal and Castrated Female Rabbits," by I. Schrire and H. Zwarenstein.

9. "South African Caddis-flies (*Trichoptera*)," by K. H. Barnard.

10. "The Discovery of a Stone Age Manganese Mine at Chowa, North Rhodesia," by R. A. Dart.

11. "Pigmentary Response in the Chameleon," by A. Zoond and Joyce Eyre.

12. "A Study in Biocoenosis," by A. J. Hesse.

13. (*a*) "The Effects on the Urinary Creatinine of Normal and Castrated Rabbits of Injections of Anterior Lobe Pituitary Extracts. (*b*) The Metabolism of Injected Creatine by Normal and Castrated Male Rabbits," by I. Schrire and H. Zwarenstein.

14. "Notes on *Rhopalota aphylla*, N.E.Br.," by R. S. Adamson.

15. "Anatomical and Cytological Studies of *Clematis brachiata*, *Clematopsis Stanleyi*, and Hybrids," by Clarice G. Crocker (communicated by Miss E. L. Stephens).

16. "The Breeding of Marine Animals," by Anne Stephenson and T. A. Stephenson.

17. "The Ascidians from the Cape Province," by W. Michaelsen (communicated by Prof. T. A. Stephenson).

18. "The Growth Changes of *Pteroplatea natalensis*," by J. L. B. Smith.

19. "Some Abnormal Specimens of the Panga," by K. H. Barnard.

20. (*a*) "Note on Relations between the Primary Minors of a 3-by-9 Array. (*b*) Note on an Overlooked Alternant," by Sir Thomas Muir.

21. "Retinal Currents," by W. A. Jolly.

22. (*a*) "Some Artefacts in Bushman Skulls suggesting Trepanning. (*b*) A Witch Doctor's Outfit from German South-West Africa," by M. R. Drennan.

23. "Climatic Changes and their Effect on Fresh-water Molluscs," by F. G. Cawston.

24. "Further Notes on the Physiology of *Teloschistes flavicans*," by J. B. CUTHBERT.

25. "The Declination at the University of Cape Town Magnetic Observatory: August 1932 to August 1933," by A. OGG and E. N. GRINDLEY.

26. "Continuous Recording of Cosmic Ray Intensities," by B. F. J. SCHONLAND and B. DELATIZKY.

27. "The Phonetics of the Hottentot Language," by D. M. BEACH.

28. "A Rapid Test for Pregnancy on *Xenopus laevis*," by H. A. SHAPIRO and H. ZWARENSTEIN.

29. "Marine Fishes of Seven Genera new to South Africa," by J. L. B. SMITH.

30. "Notes on Geaster and Disceda, particularly as regards the Eastern Cape," by N. J. G. SMITH.

Vol. XXI., parts 2 and 3, of the Society's Transactions have been issued during the year.

L. J. KRIGE, Ph.D; C. v. RIET LOWE, B.Sc.; M. RINDL, D.Ing.; B. J. RYRIE, M.B., Ch.B.; J. M. WATT, M.B., Ch.B., were elected Fellows of the Society in 1933.

Three new Members were elected during the year.

At the end of 1933 the number of Honorary Fellows was 1, Fellows 75, Members 126.

The deaths since the 1933 Anniversary Meeting of Rev. Father GOETZ, S.J. (elected Fellow 1910), and Dr. H. V. EXNER are recorded with regret.

During the year four Members resigned, and the names of two Members were struck off the list.

At the Ordinary Meeting held on 17th May 1933, it was decided to alter the constitution of the Council to include two new officers, the Honorary Librarian and the Honorary Editor of Transactions. The offices were held respectively by Mr. A. J. H. GOODWIN and Professor R. S. ADAMSON during 1933. The action of the Council in this matter was ratified by a ballot of members.

The Library of the Society has been checked and rearranged on the shelves of the Jagger Library basement and is now more accessible. A considerable number of back parts of various sets of publications have been obtained by exchange and otherwise to complete series. The Society is indebted to the Librarian of the University of Cape Town for much help in this important work.

The Society is at present receiving some 400 scientific periodicals in exchange for the Transactions.

Exchange with the following institutions has stopped:—Hamilton Scientific Association, Ontario; Kungl. Vitterhets Historie och Antikvitets Akademien, Stockholm.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1933.

Revenue.

	£ s. d.	£ s. d.
To Subscriptions collected for 1933:—		
Subscriptions collected for 1931	7 0 0	
,, ,, 1932	27 0 0	
,, ,, 1933	252 14 1	
,, for 1933, held by Neill & Co.	2 0 0	
,, collected for 1934	3 7 8	
Life Subscription..	25 0 0	
Subscriptions collected in advance for 1933	4 3 0	
Outstanding Subscriptions at December 31, 1933	65 0 0	
	386 4 9	
Less: Outstanding Subscriptions as in Statement, December 31, 1932, £55; Subscriptions collected in 1933 for 1934, £3 7s. 8d.	58 7 8	
		327 17 1
,, Entrance Fees		3 0 0
,, Interest received:—		
On £408 New Union of S.A. 5 per cent. Stock to September 30	21 5 11	
On money in Savings Bank Department of Standard Bank	2 12 3	
On money in Cape of Good Hope Savings Bank	2 0 0	
		25 18 2
,, Sale of Publications in 1933	18 4 7	
Plus: Amount due for Sales in 1933 ..	1 0 11	
Amount paid to Neill & Co. and held by them for Sales by Society	3 5 9	
Sales Account, Neill & Co., held by them..	3 10 10	
	26 2 1	
Less: 1932 Accounts paid in 1933	5 2 9	
		20 19 4
,, Excess of Amount received for Union Stock or redemption over the amount in Assets Statement, 1932		8 0 0
		£385 14 7

Expenditure.

	£ s. d.	£ s. d.	£ s. d.
By Publications:—			
Cash paid to Neill & Co. for Printing, etc.	253 11 3		
Losses on Exchange	2 4 7		
Cost of Bank Drafts	0 4 0		
Amount due for Vol. XXI., Part 3	110 2 0		
		366 1 10	
Less: Amount due for Vol. XXI., Part 1, issued 1932	113 17 2		
Amount received for extra proof correction.. ..	0 19 6		
Carnegie Fund grant by Research Grant Board	100 0 0		
		214 16 8	
		151 5 2	
Less: Receipts from Sales of extra Reprints	7 3 0		
Amount due for Sales in 1931	1 5 9		
	8 8 9		
Less: Amount due for Sales on December 31, 1932	5 12 0		
		2 16 9	
			148 8 5
,, Compilation of International Catalogue of Scientific Papers			16 16 0
,, Clerical Assistance and Work in Library			84 0 0
,, Local Printing and Stationery			42 2 9
,, Postages and Petties			21 5 6
,, Bank Charges for Commissions, Ledger Fees, etc.		3 10 11	
Less: Commissions paid by Members		1 19 9	
			1 11 2
,, Hire of Rooms and Caretaker			6 6 0
,, Insurance of Library and Insurance of back Numbers with Neill & Co. ..			1 8 9
,, Expenses in getting back Numbers of German Periodicals ..			3 19 0
,, Purchases: Indexes of Papers of Royal Society of London ..		0 16 10	
Flora Capensis, Vol. V., Section 2 (Supplement) ..		0 8 0	
			1 4 10
,, Contribution to Herschel Centenary Committee Guarantee Fund ..			10 0 0
,, Profit in Year 1933..			48 12 2
			£385 14 7

	£	s.	d.
Committee Guarantee Fund ..	10	0	0
,, Profit in Year 1933	48	12	2
	£385	14	7

ASSETS AND LIABILITIES AS AT DECEMBER 31, 1933.

Assets.*	£	s.	d.
Money in Savings Bank Department of Standard Bank ..	264	4	9
Balance at Standard Bank as per Pass Book	28	12	8
Money in Cape of Good Hope Savings Bank	302	0	0
Arrears of Subscriptions, as in Statement for 1932, £55; less £34 paid in 1933 and £4 struck off as irrecoverable	17	0	0
Arrears of Subscriptions for 1933, £50; less £2 struck off as irrecoverable	48	0	0
Amount due for Sale of Publications in 1932	1	15	6
Amount due for Sale of Publications in 1933	1	0	11
Amount due for Sale of Extra Reprints in 1931	1	5	9
Amount due for Sale of Extra Reprints in 1932, £3 6s. 3d.; less £3 6s. 3d. struck off as irrecoverable		—	
	£663	19	7

Liabilities.	£	s.	d.	£	s.	d.
Subscriptions received in advance for 1934 ..				3	7	8
Amount owing for Printing, etc., Vol. XXI., Part 3, issued December 1933	110	2	0			
Less: Amount held by Neill & Co. for Society:—						
Sales of Publications by Society £3 5 9						
Sales of Publications by them 3 10 10						
Subscription for 1933 .. .. 2 0 0						
	8	16	7			
				101	5	5
Amount owing Wheldon & Wesley for Flora Capensis, Vol. V., Section 2 (Supplement)				0	8	0
Excess of Assets over Liabilities:—						
Amount at December 31, 1932 ..	510	6	4			
Plus: Profit in 1933	48	12	2			
				558	18	6
				£663	19	7

* Exclusive of value of Library and Publications of the Society held in Stock.

LAWRENCE CRAWFORD,
Hon. Treasurer.

We hereby certify that we have examined the above Accounts of Revenue and Expenditure, and of Assets and Liabilities, with the books, vouchers, and other documents relating thereto, and that in our opinion these Accounts set forth a correct statement of the affairs of the Society.

J. W. C. GUNN.
B. J. RYRIE.

February 9, 1934.

NOTE.—The Council wishes to point out that in 1933 only two Parts of Transactions were issued and that no money was spent on binding. This unsatisfactory position was due to the fact that the Society received no Government Grant in 1933, and, having no definite assurance that the Grant would be restored in 1934, the Council did not wish to incur a loss of £245 as in 1932.

In addition to the normal exchanges, which have been maintained, the following new exchanges have been arranged:—Marine Biological Laboratory, Woods Hole, Massachusetts; Academy of Science, Allahabad, India; Arnold Arboretum, Harvard University, Jamaica Plain, Massachusetts; Botanical Society of India, Lucknow.

The Library wishes gratefully to acknowledge the following gifts:—

From the author, The Moths of South Africa, by A. J. T. Janse; from the author, Three Reprints of Papers, by Dr. Gerhard Nilsson, Sweden; from the Universität, Giessen, Untersuchungen über Regenschwankungen und Häufigkeit unter Berücksichtigung des Angaus, ausgeführt am Beispiel Süd-Afrikas, by Jung; from the author, Thirteen Reprints of Papers, by Prof. A. Arcangeli; from the author, La non-specifité de la reaction de Beam en matiere de Haschich, by Dr. Henri Trollé; from the British South Africa Company, Report of Mazoe Citrus Experimental Station for 1932; from the McGregor Museum, Kimberley, Bantu Tribes of South Africa, Vol. II., sections 2 and 3, by A. M. Duggan-Cronin; from La Fondation Singer-Polignac, Paris, Les Peintures Rupestres schématiques de la Peninsule Iberique, by M. l'Abbé Breuil; from the author, Three Reprints of Papers, by Prof. F. D. Adams, McGill University.

The following books were bought during the year:—Flora Capensis, Vol. V., section 2, Supplement; Royal Society Indexes, (1) Proceedings, 1800–1905; (2) Proceedings, 1905–1930, and Philosophical Transactions, 1901–1930.

876 cards were sent by Dr. K. H. Barnard to the International Catalogue of Scientific Literature during the year.

As the Society had no Government Grant, it was not possible to bind any journals during 1933.

A deputation from the Society interviewed the Minister for Education and put before him arguments in favour of the continuance of the former Government Grant. The Minister, while unable to comply in 1933, promised to give the matter sympathetic consideration in framing the Estimates for 1934.

A memorandum from Council was submitted to the Minister for the Interior pointing out certain difficulties in the proposed Ancient Relics Act. The Minister replied that the Act had been redrafted, and that the report upon which the Society had acted no longer represented the proposed Bill.

Dr. B. F. J. Schonland, Honorary General Secretary in 1933, has been appointed as a Carnegie Travelling Fellow for 1934.

B. F. J. Schonland,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 18, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. Ogg, was in the Chair.

Business:—

With the addition of the words "It was resolved that a letter of condolence be sent to Mrs. Spilhaus" to the obituary notice of Sir Thomas Muir, the Minutes of the Meeting held on March 21, 1934, were confirmed.

Professor D. M. Beach was elected to Membership.

E. C. Chubb, proposed by the Hon. General Secretary, and seconded by I. Schapera, was nominated for Membership.

Communications:—

"The Archaeology of the Prehistoric Settlements in the Heilbron Area," by P. W. Laidler (communicated by R. A. Dart).

"Researches on Chlorosis in Deciduous Fruit Trees," by W. E. Isaac (communicated by R. S. Adamson).

A general account was given of the nature of chlorosis, and of some of the chief conditions by which it may be induced. Then followed a resumé of the experiments carried out on the chlorotic peregrine peach-trees growing on Krom Farm, Elgin. Observations were also made on eighty-eight chlorotic trees which were not given any special treatment.

The experiments were divided into the following five groups:—(*a*) Experiments with lime. (*b*) Experiments with sulphur. (*c*) Experiments with manganese sulphate. (*d*) Experiments with manganese sulphate and mineral fertilizers. (*e*) Experiments with copper sulphate.

The results indicate the following: (i) In about 10 per cent. of cases chlorosis tends to pass away. (ii) The sick condition of the Krom Farm peach-trees seems to be due to two distinct causes. (iii) Copper added as copper sulphate solution in a concentration of about 20 p.p.m., seems to cure the chlorotic condition. There are beneficial effects with lower concentrations. (iv) Additions of potash bring about an improvement in the trees. (v) Additions of lime do not exert a beneficial influence, and thus the trouble would not seem to be due to excess of available manganese, aluminium or iron. (vi) The trees are not in any way suffering from a deficiency of manganese, and evidence is presented indicating that chlorosis is not due to a deficiency of magnesium.

"Smithfield Implements from a Natal Coast Site," by J. Gordon Cramb (communicated by R. A. Dart).

"Report on Human Skeletal Remains from Karridene Site," by A. Galloway and L. H. Wells (communicated by R. A. Dart).

"A Further Note on Human Skeletal Remains from the Natal Coast," by L. H. Wells (communicated by R. A. Dart).

Exhibitions:—

"Peninsula Clays and their Economic Values," By H. Jacobs (communicated by J. Smeath Thomas).

A survey of the usable ceramic clays from various sources in and about the Cape Peninsula. The exhibition consisted of test-pieces, fired, and in certain instances glazed with locally procured glazes. It was shown that material was available which would yield stoneware, porcelain and similar ceramic ware of value. The exhibition was the result of scientific laboratory experiments carried out with a view to testing the value of local clays.

The Secretary exhibited a copy of a volume, "Colombo," which had been presented to the Library of the Society by the City of Genoa, through the Italian Legation. The Treasurer reported that the Legation had been suitably thanked for their generous gift.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 16, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. Ogg, was in the Chair.

Business:—

The Minutes of the Meeting held on April 18, 1934, were confirmed.

Miss M. G. Mes, proposed by Miss E. L. Stephens, and seconded by R. S. Adamson, was nominated for Membership.

It was noted that E. C. Chubb had formerly been a Member of the Society; re-election is therefore not necessary.

The Hon. Secretary announced that the following had been proposed for Fellowship of the Society:—John Jackson, proposed by H. H. Paine, H. Stephen, A. W. Roberts, H. E. Wood; Adrianus Pijper, proposed by H. H. Paine, Henry Stephen, John Philips, J. P. Dalton; William Pugh, proposed by J. Smeath Thomas, H. A. Reyburn, R. H. Compton, E. L. Stephens, and W. Campbell; Isaac Schapera, proposed by C. van Riet Lowe, H. A. Reyburn, Sir J. C. Beattie, and A. Young; Thomas Alan Stephenson, proposed by K. H. Barnard, William Campbell, J. Smeath Thomas, and Sir J. C. Beattie.

Communication:—

"The South African Species of the Triglid genera : *Lepidotrigla* and *Peristedion*," by J. L. B. Smith.

The paper revises the South African species of *Lepidotrigla*. *L. Faurei* and *L. Natalensis* are maintained as distinct species, and one new species is described. A new species of *Peristedion* is also described. Figures of all the species are given.

Exhibitions:—

"Some Peculiar Fish Scales," by K. H. Barnard.

"Whorls in a Lamp-glass," by E. L. Gill.

The exhibit consisted of a perfect involute and evolute figure traced on the inner surface of a lamp-glass by an oil flame.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 20, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. Ogg, was in the Chair.

Business:—

The Minutes of the Meeting held on Wednesday, May 16, 1934, were confirmed.

Miss M. G. Mes, was elected to Membership of the Society.

Communications:—

1. "Diurnal and Secular Variations of the Earth's Magnetic Field at Cape Town," by A. Ogg, E. N. Grindley, and B. Gotsman.

In a former communication (Minutes of Proceedings, October 18, 1933), the monthly means of the declination and the secular variation ($+4'{\cdot}2$) from August 1932—August 1933, were given. The mean variation from seven such determinations extending to February 1933—February 1934, gives for all days of the month a value of $+3'{\cdot}8$ (*i.e.*, to the East). This determination that the secular change of declination in this latitude is of the order of $+4'$, is of importance since magnetic tables gives the value $+10'$ for the epoch 1925.

A Fourier analysis of the declination referred to meridian 18° 30′E. and expressed in the form:—

$$D = -24° - S/24 - c_1 \sin(\theta + \phi_1) - c_2 \sin(2\theta + \phi_2) - c_3 \sin(3\theta - \phi_3) - c_4 \sin(4\theta + \phi_4)$$

gives a good agreement between corresponding months of the year, as the following example for the ten least disturbed days of the month shows.

Aug. 1932—

$S/24$	c_1	ϕ_1	c_2	ϕ_2	c_3	ϕ_3	c_4	ϕ_4
$43'{\cdot}4$	$0'{\cdot}87$	$257°{\cdot}4$	$1'{\cdot}46$	$117°{\cdot}0$	$1'{\cdot}37$	$299°{\cdot}1$	$0'{\cdot}67$	$125°{\cdot}1$

Aug. 1933—

39′·1 0′·90 258°·4 1′·43 105°·8 1′·37 328°·5 0′·61 123°·3

Diurnal and secular variation curves of the horizontal and vertical intensities were also shown.

The monthly means of the horizontal intensity H and the range R in gamma units, for the ten least disturbed days of the month, are given in the following table. The table also gives the range of the vertical intensity Z. for the year 1933—R_1 from the first minimum of the day to first maximum, R_2 from first maximum to second minimum, R_3 from second minimum to second maximum in gamma units.

		H.	R.	Z. R_1.	Z. R_2.	Z. R_3.
1932.	Aug.	15133	28			
	Sept.	15125	30			
	Oct.	15123	27			
	Nov.	15120	16			
	Dec.	15113	24			
1933.	Jan.	15107	21	9	37	35
	Feb.	15095	20	14	34	30
	Mar.	15086	22	19	39	33
	Apr.	15067	21	15	34	33
	May	15062	28	14	11	13
	June	15055	25	13	9	10
	July	15049	27	14	9	12
	Aug.	15042	31	19	13	15
	Sept.	15031	31	19	13	14
	Oct.	15028	22	11	24	28
	Nov.	15015	28	7	18	22
	Dec.	15017	26	5	12	21

The small range of H for November 1932, was due to instrumental difficulties caused by condensation of moisture on the lenses.

From the above data the secular variation of the horizontal intensity is −97 gamma, probably the largest secular variation at any point on the earth's surface between the latitudes 60° N. and 60° S.

2. "The Vegetation and Flora of Robben Island," by R. S. Adamson.

3. "Studies in Deciduous Fruit: The Effect of Time of Picking on the Keeping Quality of Plums—with especial Reference to the Internal Browning of the Kelsey Plum," by I. Doneen.

A description is given of investigations on the effect of Time of Picking on the keeping quality in store of two varieties of plum (Gaviota and Kelsey). The plums were chosen from four orchards differing in soil, climate, and cultural treatment. They were then kept at 34°–36° F. for 30 days and at room temperature for 4 or 12 days, and percentage breakdown recorded.

It has been found that Gaviota plums should not be kept in store for a period much longer than 30 days, as breakdown increases greatly with increased time in store. Gaviota plums that were picked early showed the least amount of breakdown.

Kelsey plums in store exhibited two types of breakdown: Internal and Invasive Browning. The extent of browning is associated with the amount of skin colour of the plum on picking. Early picked plums failed to colour up in store and showed no browning after 30 days in store and 21 days at room temperature. It is suggested that Kelsey plums for export should be picked with 5–8 per cent. colour and should not be kept in store for periods much longer than 30 days.

No definite correlation between Index Figure and breakdown in store has been found for both Gaviota and Kelsey Plums.

4. "The South African Literary and Scientific Institution, 1833–1857," by L. Crawford.

The South African Literary Society was started in 1824, but as John Fairbairn and Thomas Pringle were two of its sponsors, it encountered the hostility of the Governor, Lord Charles Somerset. He refused to grant it a licence and the project was dropped till 1829. The Society then began to hold meetings, papers were read and prizes offered for essays, one of these being limited to students of the South African College, founded in that same year 1829.

The South African Institution was founded also in 1829, and was a society much on the same lines, but Cape Town was too small for two such societies, and in 1832 they amalgamated and became the South African Literary and Scientific Institution. Reports of the meetings and papers read appeared in the S.A. Quarterly Journal, but in 1835 that Journal came to an end and information about the later history of the Institution is difficult to find. The Institution's own Minute books, etc., have disappeared.

In 1834 Sir John Herschel came to South Africa. He was a strong supporter of the Institution during the four years he was here; for nearly three years he was President. He specially pressed the claims of Meteorology on the Institution. A full account of the presentation to him on his departure was given in the Commercial Advertiser.

In 1836 the Cape Almanac speaks of the rooms of the Institution and its Museum. After 1838 it is certain the Institution declined, so much that in 1850 John Fairbairn suggested in the Commercial Advertiser that a new Institution be formed, and for permanence should be attached to the Public Library. This appeal met with no response. The Institution disappeared from the list of Societies in the Almanac and Annual Register in 1858, so it may be taken that it came to an end in 1857, but from the first annual report of the S.A. Museum in 1856 it is learned that, in the year previous to

that, what was left of its collections, books, etc., had been handed over to the Museum.

Exhibition:—

"Some Desert-living Animals," by R. F. Lawrence.

Specimens of the rare rock lizard *Platysaurus capensis* from Namaqualand were exhibited and the colouring of the sexes, habits, and distribution were commented on.

A series of photographs were put on the screen illustrating the habits and protective colouration of some typical desert animals; the mechanisms for stridulating or hissing, used by many desert animals were described in different classes of arthropods.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 18, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. Ogg, was in the Chair.

Business:—

The Minutes of the Meeting held on Wednesday, June 20, 1934, were confirmed.

P. W. Laidler, proposed by J. Hewitt, seconded by the Hon. General Secretary, was nominated for Membership.

Communications:—

1. "Contributions to our Knowledge of the Freshwater Algae of Africa. No. 11. Algae from a Pan in Southern Rhodesia," by Florence Rich, M.A., F.L.S. (communicated by Miss E. L. Stephens).

This collection of algae was made from a pan at Old Ngamo, five miles north of Ngamo station, and is of special interest as the first collection from the Rhodesias to be systematically examined. It has proved very rich, especially in Desmids, and has produced several new and interesting species as well as many new records for South Africa. The Affinities of the algae present are much more with Central Africa than with South Africa, the general facies being that of a small tropical lake, though this pan dries up more or less completely during the dry season. The collection was made on July 4, 1930. *i.e.* mid-way through the dry season, and the conditions were evidently very favourable for sexual reproduction, for about 50 species were observed to be in that state. This included 25 species of Desmids, 10 of which were previously known only in the vegetative state. The zygospores of these Desmids are thus now described for the first time.

2. "On a Corosion Problem," by E. NEWBERY.

3. "New South African Solifugae," by R. F. LAWRENCE.

Exhibition:—

"Some Oceanographic Results of the 'Discovery' Survey," by K. H. BARNARD and W. J. COPENHAGEN.

Examples of oceanographical data collected by the R.R. Ships "Discovery I and II," and papers by the scientific staff were brought before the notice of the Society. The bearing of this work on the South African seas was discussed.

Resolution:—

"In view of the vast amount of oceanographical data (chemical, physical, biological, and meteorological) collected in the Antarctic regions, and its bearing on the oceanographical matters in the seas around the South African coasts, this Society desires to place on record its appreciation of the work of the 'Discovery' Committee and their scientific staff, and earnestly hopes that the work will continue."

Proposed by W. J. COPENHAGEN, seconded by K. H. BARNARD. It was resolved that this be submitted to the Council of the Society.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 15, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. OGG, was in the Chair.

Business:—

The Minutes of the Meeting of July 18, 1934, were confirmed.

Mrs. ALICE BOWLER KELLEY, proposed by E. L. GILL, seconded by the Honorary General Secretary, was nominated for Membership.

P. W. LAIDLER was elected to membership.

A notice from the Sixth International Botanical Congress, Amsterdam, 1935, was read. "Motions dealing with Nomenclature for consideration by the Congress should be sent, before January 1, 1935, to Dr. T. A. SPRAGUE, The Herbarium, Royal Botanic Gardens, Kew, Surrey, England. Motions must be presented in the form of additional articles (or amendments) to the International Rules, as briefly as possible, in Latin, English, French, German, or Italian. At least 100 printed copies must be presented. Only motions relating to new points which were not settled at previous congresses can be presented." (Precis.)

Communications:—

"The Influence of Testicular and of Urinary Extracts on the Creatinine Excretion in Rabbits," by R. W. S. CHEETHAM, I. SCHRIRE, and H. ZWARENSTEIN.

(*a*) Testicular extract increases the excretion of creatinine in the normal rabbit transiently by approximately 40 per cent.

(*b*) Testicular suspensions decrease the creatinine elimination in the normal rabbit by approximately 40 per cent. This too is a transient effect.

(*c*) Injection of urinary extract of the male sex-hormone first decreases the creatinine excretion by 30 per cent. and then increases the elimination by 30 per cent. approximately. This is a diphasic effect and passes off within 4 days of the injection.

There is evidence to show that the testes secrete two factors. One of these increases and the other decreases the creatinine excretion in the rabbit. Normally the anterior lobe of the pituitary controls these testicular secretions.

"The Effect of Hypophysectomy and Castration on Muscle Creatine in *Xenopus laevis*," by B. G. SHAPIRO and H. ZWARENSTEIN.

(1) The average creatine content of the hamstring muscles of the S. A. clawed toad is 400 mgrm. per 100 grm.

(2) There is considerable variation between different individuals, 350–435 mgrm. per 1000 grm.

(3) In any single individual the hamstrings of the right and left legs contain the same amount of creatine.

(4) Removal of anterior or both lobes produces a steady decline in muscle creatine. Five months after operation the hypophysectomised animals contain an average of 18 per cent. less creatine than the captive control animals.

(5) Removal of the testes and of the ovaries have no effect up to five months.

"The Bio-Assay of the Gonadokinetic Principle of the Anterior Pituitary," by S. HONIKMAN, H. A. SHAPIRO, and H. ZWARENSTEIN.

A curve has been constructed relating dosage of an acid extract of anterior pituitary (sheep and goats) to percentage response (ovulation plus oviposition) in *Xenopus laevis* during the month of July (breeding season).

Fifty animals were used for each point. The toads were kept at a temperature of 18° to 20° C. Readings were taken twenty-four hours after injection. The laboratory age of the animals did not exceed two weeks.

The unit is defined as the amount of original tissue required to produce a 50 per cent. response. This was found to be 3·8 mgrm., *i.e.* 263 units per grm.

"Vesalius on China-Root," translated from the Latin by BENJAMIN FARRINGTON.

Extracts from a letter of Andreas Vesalius to Dominus Joachim Roelants written at Ratisbon, June 13, 1546. At this time China-root (*i.e.* China-smilax, a species of sarsaparilla) had an enormous reputation as a specific for various diseases. Vesalius, in lively and sarcastic style, exposes the inadequacy of the basis on which this reputation rested.

A. J. H. GOODWIN,
Hon. General Secretary.

ANNUAL MEETING.

The Annual Meeting of the Society was held on Wednesday, September 19, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. OGG, was in the Chair.

Business:—

The following Candidates were duly elected Fellows of the Society:—J. JACKSON, D.Sc.; A. PIJPER, M.D.; W. PUGH, Ph.D.; I. SCHAPERA, Ph.D.; T. A. STEPHENSON, D.Sc.

The Annual Meeting was followed by an Ordinary Meeting.

Business:

Minutes of the Meeting held on Wednesday, August 15, 1934, were confirmed.

Miss D. HOLLAND, proposed by Miss M. WILMAN, seconded by R. S. ADAMSON, was nominated for Membership.

Mrs. A. BOWLER KELLEY was elected to Membership.

"Notes on Nomenclature of South African Compositae," by M. R. LEVYNS.

Some changes in nomenclature are shown to be necessary. *Stoebe tortilis* DC is synonymous with *Disparago ericoides* Gaertn. *Stoebe cinerea* Thunb. is none of the plants to which that name is usually applied, but a plant with a restricted distribution growing abundantly on Table Mountain. The name *Stoebe plumosum* Thunb. is revived.

The name *Disparago Kraussii* Sch. Bip. should be applied to one of the two specimens on which the species was founded. The other is *Disparago laxifolia* DC. *Disparago seriphioides* DC and *Disparago hoffmanniana* Schlechter are synonymous with *Disparago lasiocarpa* Cass.

In *Elytropappus* several new combinations are necessary. Thus *E. hispidus* nov. comb. = *E. spinellosus* Cass.

E. scaber nov. comb. = *E. glandulosus* Less var. *microphyllus* DC (partly).

E. gnaphaloides nov. comb. has as synonyms *E. canescens* DC, *E. ambiguus* DC, *E. glandulosus* Less. var. *pallens* DC, and *E. glandulosus* Less. var. *ambiguus* Harv. *E. glandulosus* Less. and *E. glandulosus* Less. var. *longifolius* DC are defined.

Resolution:—

The following resolution, proposed by the Hon. Treasurer and seconded by R. S. Adamson, was passed: –

"That in connection with the account of the Royal Society of South Africa with the Post Office Savings Bank, the Postal authorities be authorised to accept the signature of the Hon. Treasurer."

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 17, 1934, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. A. Ogg, was in the Chair.

Business:—

The Minutes of the Annual Meeting of September 19, 1934, were confirmed.

Miss D. Holland was elected to Membership.

The Vice-President gave notice that the following were recommended by Council for the incoming Council of 1935:—

President, A. W. Rogers; Hon. Treasurer, L. Crawford; Hon. General Secretary, A. J. H. Goodwin; Hon. Editor of Transactions, R. S. Adamson; Hon. Librarian, E. Newbery; Council, K. H. Barnard, J. W. Bews, A. Brown, J. P. Dalton, H. G. Fourcade, J. Jackson, C. van Riet Lowe, A. Ogg, M. Rindl.

The date of the Anniversary Meeting and Election was fixed for the evening of Wednesday, March 20, 1935, in the South African Association Chambers, Church Square.

Communications:—

"A New Lamellibranch from the Upper Dwyka Beds of South-West Africa," by F. R. C. Reed (communicated by S. H. Haughton).

"Variations in the Ovarian Response of Xenopus to the Gonadokinetic Principle of the Anterior Pituitary. I," by S. Honikman, H. A. Shapiro, and H. Zwarenstein.

Anterior pituitary extract assayed on frogs in July gave 263 units per grm. original tissue. A similar assay in October gave 77 units per grm. In July the ovary-body weight ratio was 110, in October, 80.

It was found that the potencies of extracts from different batches of anterior pituaries prepared at the same time and assayed on animals from the same stock varies considerably. It would therefore be premature to conclude that the correlation between the ovary-body weight and the number of units per grm. observed above is a true correlation.

Exhibition:—

"Some Rainmaking and Divining Methods of the Bakxatla," by I. SCHAPERA.

Rain-making bowls, and "divining bones" used by the Bakxatla were exhibited, and an account of the methods employed in their use was given.

Demonstration:—

"A Proposed Method for the Quantitative Estimation of Phytoplankton," by W. J. COPENHAGEN.

A new type of apparatus was demonstrated and described for the quantitative estimation of phytoplankton. Certain advantages over existing apparatus is claimed.

1. More representative sample is obtained.
2. Complete removal of catch can be effected.
3. Catch can be collected at speeds up to 8 knots.
4. A rapid interchange of filtering surfaces is possible.

A. J. H. GOODWIN,
Hon. General Secretary.